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Water Monitoring Project
Water Monitoring Management

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NEW JERSEY AMBIENT MONITORING PROGRAM

REPORT ON MARINE AND COASTAL WATER QUALITY

1993 - 1997

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NEW JERSEY AMBIENT MONITORING PROGRAM

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New Jersey Department of Environmental Protection
ROBERT C. SHINN, Jr.
COMMISSIONER

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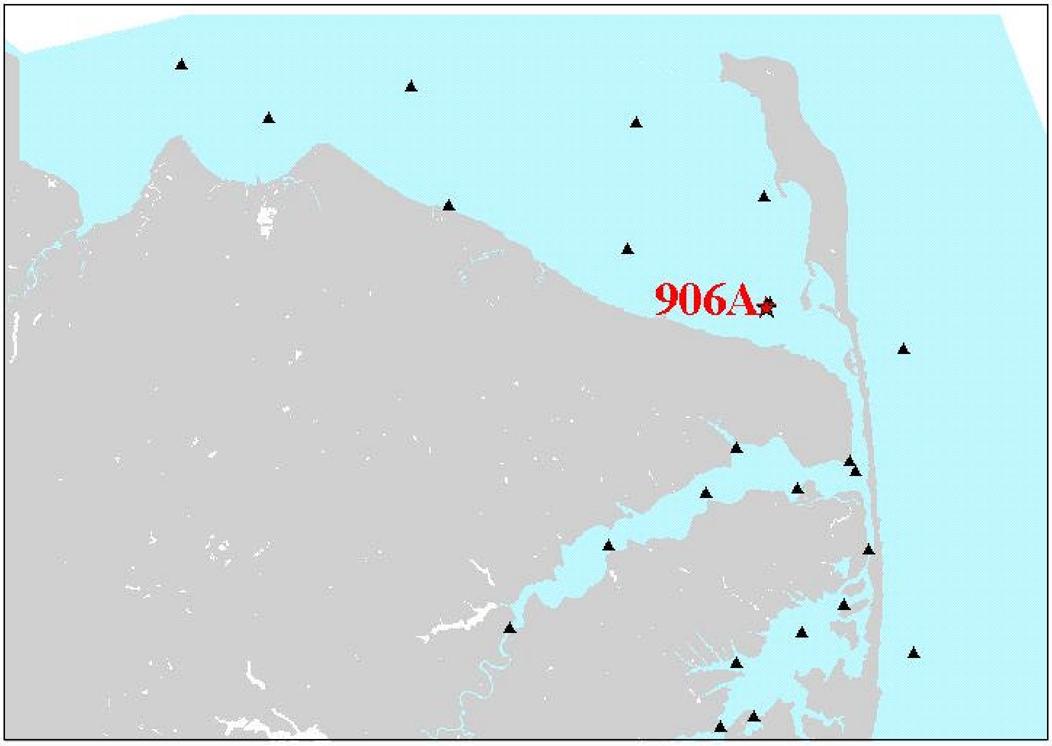
TABLE OF CONTENTS

FIGURES

TABLES

Sampling Locations:
Estuarine Monitoring

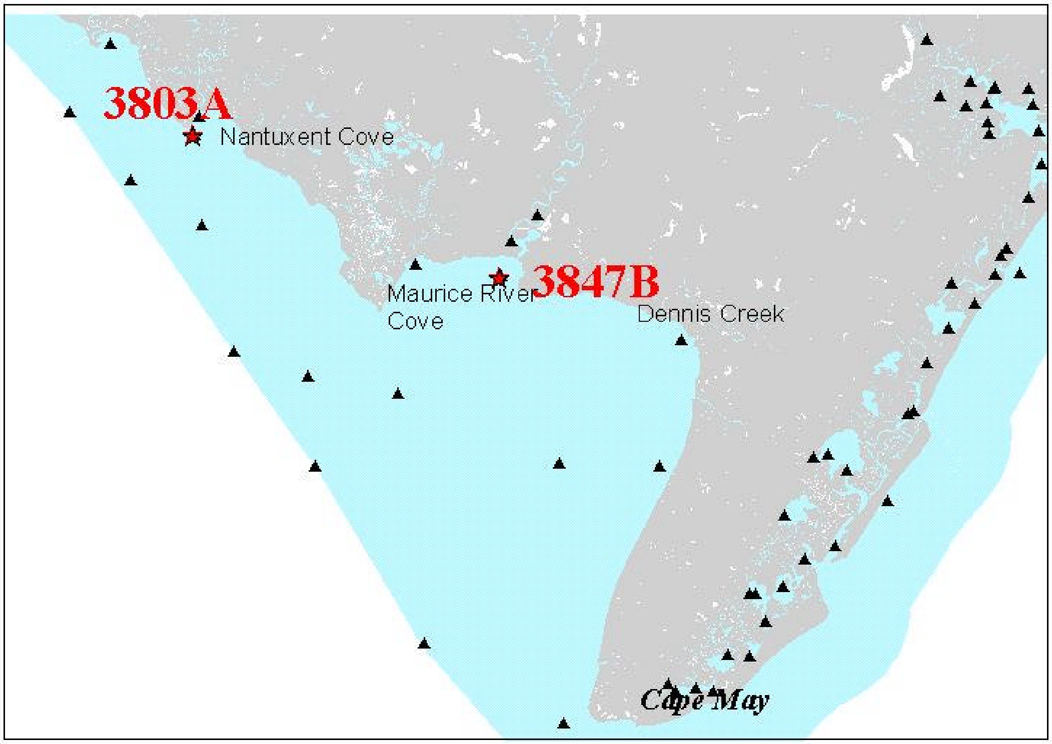


Raritan Bay
Sandy Hook Bay
Navesink River
Shrewsbury River

Note:
Station 906A (shown in red)
is used as an example
in the text.

NJDEP Bureau of Marine Water Monitoring

Sampling Locations: Estuarine Monitoring



Delaware Bay
- **Cohansey Cove**
- **Nantuxent Cove**
- **Maurice River**
- **Dennis Creek**

Note:
Stations 3847B and 3803A (shown in red) are used as examples in the text.

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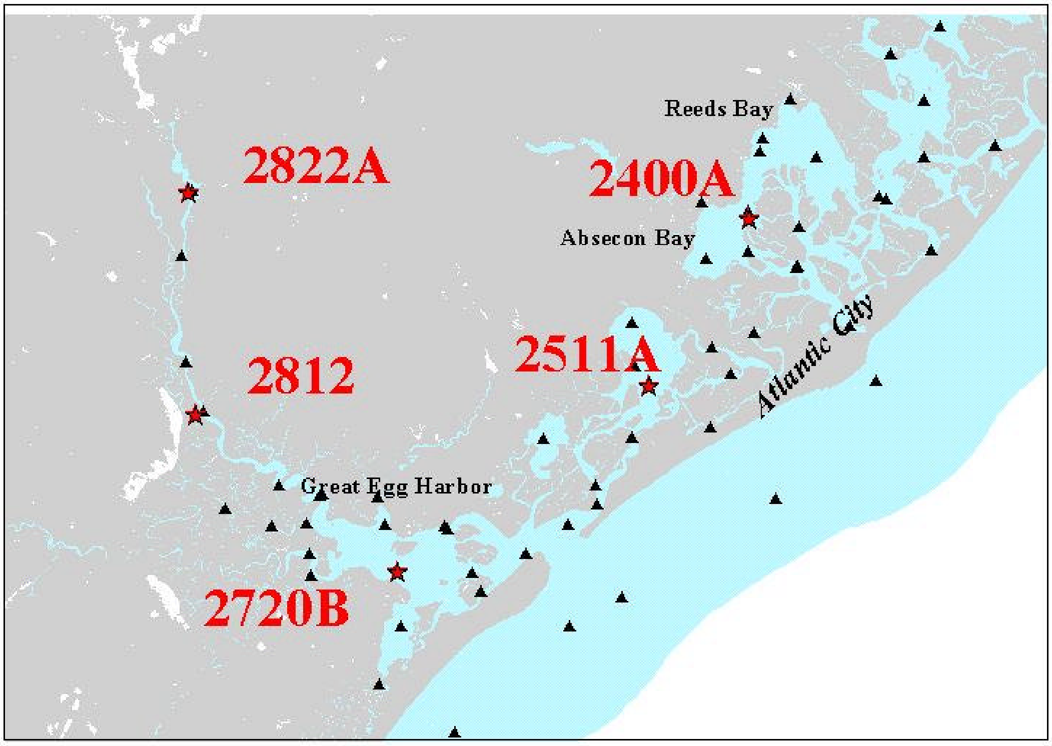
Sampling Locations: Estuarine Monitoring



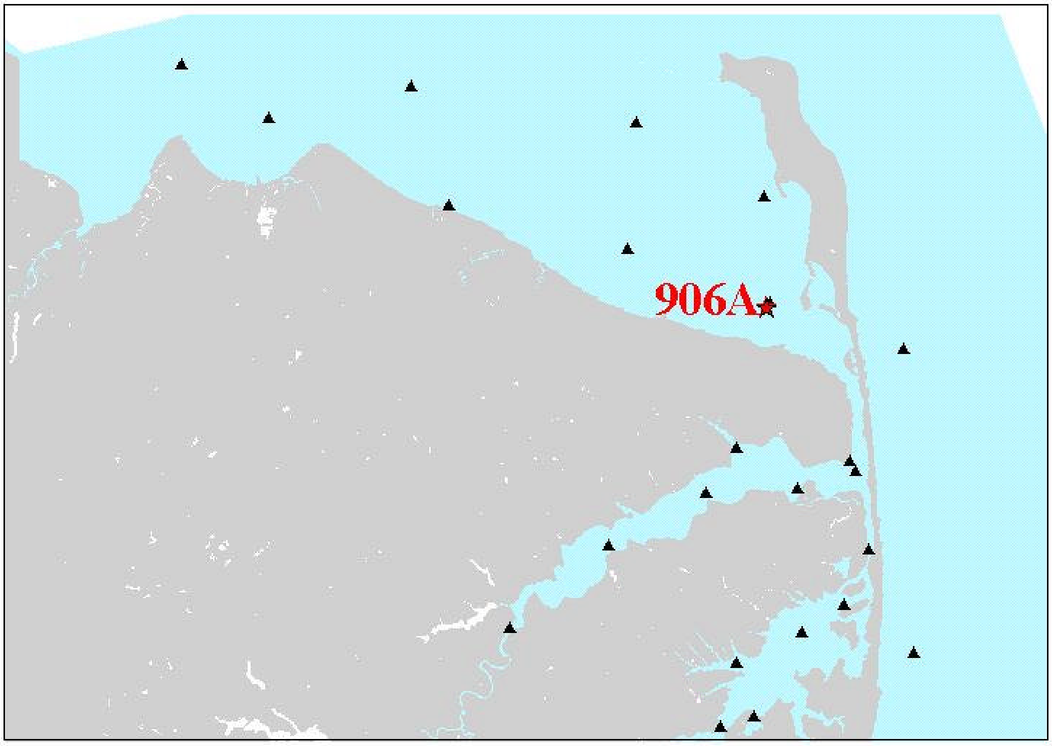
Back Bays: Great Bay to Great Egg Harbor

- Little Bay
- Reeds Bay
- Absecon Bay
- Lakes Bay
- Scull Bay
- Great Egg Harbor

Note:
Stations 2511A, 2400A, 2822A, 2812, and 2720B
(shown in red) are used as examples in the text.

NJDEP Bureau of Marine Water Monitoring

Sampling Locations: Estuarine Monitoring



Raritan Bay
Sandy Hook Bay
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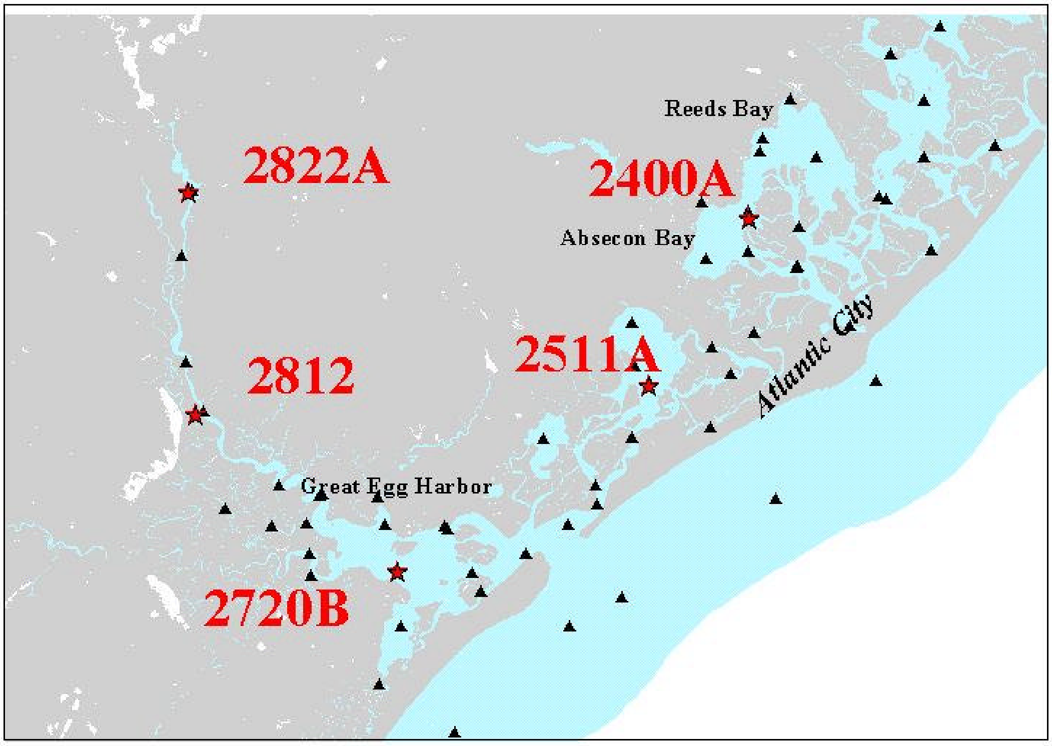
Note:
Station 906A (shown in red) is used as an example in the text.

NJDEP Bureau of Marine Water Monitoring

Sampling Locations: Estuarine Monitoring



Back Bays: Great Bay to Great Egg Harbor

- **Little Bay**
- **Reeds Bay**
- **Absecon Bay**
- **Lakes Bay**
- **Scull Bay**
- **Great Egg Harbor**

Note:
Stations 2511A, 2400A, 2822A, 2812, and 2720B (shown in red) are used as examples in the text.

NJDEP Bureau of Marine Water Monitoring

EXECUTIVE SUMMARY

During the period 1993 – 1997 nutrient concentrations in the coastal waters of New Jersey decreased, reflecting an overall improvement in water quality. However, dissolved oxygen concentration in an area bounded by southern Barnegat Bay on the north and Great Egg Harbor River on the south were significantly depressed as compared to previous sampling periods.

INTRODUCTION

Water quality in the coastal waters of New Jersey is adversely impacted by numerous anthropogenic activities. These include:

- Commercial/residential development and its associated stormwater runoff,
- Recreational uses such as boating, fishing, and swimming and the associated waterfront development, and
- Wastewater disposal.

As a result, problems such as anoxic conditions, phytoplankton blooms, public health concerns and/or as change in abundance of commercially valuable fish and shellfish have frequently been documented.

When the Department of Environmental Protection began to investigate problems such as the green tide near Atlantic City and Ocean City (1984 and 1985) and the brown tide in Barnegat Bay (1988), minimal background data existed on basic water quality at these locations. An ongoing sampling and analysis program began in July 1989. Samples were collected quarterly at approximately 200 sites along the coast of New Jersey and analyzed for a series of parameters. These data have been periodically summarized and evaluated. (See: <u>Report On Estuarine Water Quality 1989-1990</u> by Robert Connell and Laurie Messler and <u>Report On Marine And Coastal Water Quality 1990 - 1993</u> by Sandra Groppenbacher.)

This report describes the results of this monitoring program for data collected from July 1993 to June 1997. This monitoring program produces high quality data for parameters such as temperature, salinity, dissolved oxygen, and the major nutrients affecting primary productivity. Fecal coliform bacteria have been included as a means to assess the sanitary quality of the waters and to test for correlation with the other parameters being analyzed. Fecal coliform bacteria are an indicator of the presence of fecal wastes and the possible contamination of the water column by pathogenic organisms (disease causing organisms).

The Department of Environmental Protection has an additional and more extensive monitoring program to test coastal waters for coliform bacteria. The additional data are regularly summarized and interpreted in accordance with the National Shellfish Sanitation Program requirements. This program evaluates the sanitary quality of coastal waters to determine the suitability and safety of shellfish harvested from those waters for human consumption. Recent reports are available electronically at **http:/www.state.nj.us/dep/dsr/bmw/index.htm**.

METHODS

Sampling

Over 200 sampling stations are located throughout New Jersey's estuaries and the Atlantic Ocean (within 4 kilometers of the coastline). This report includes data based on samples collected between July 1, 1993 and June 30, 1997. An effort was made to obtain a sample at each station at least once during each quarterly sampling period.

Sampling stations were chosen for one of four reasons:

- To be representative of a major body of water;
- To be representative of fresh water inputs into an estuary;
- To be representative of water being exported from an estuary to the ocean; or
- To be representative of water quality in the vicinity of a discharge into the ocean.

For the previous reports, samples were collected in conjunction with the coliform bacteria sampling mandated by the National Shellfish Sanitation Program (NSSP). Therefore, sampling stations during those periods coincided with existing stations used for the NSSP monitoring work and sampling of an entire estuary from fresh water to open ocean was not feasible. However, separate nutrient sampling assignments were established in 1993.

Samples were analyzed for salinity, dissolved oxygen, suspended solids and nutrients.

Samples listed with a sample depth of zero were obtained by surface grab. Due to equipment problems, no bottom samples were collected. Table 1 shows sample container types, methods of preservation and holding times for each parameter.

Further details on the preparation of sample containers, labware and reagents can be found in the Leeds Point Chemistry Laboratory Standard Operating Procedures Manual of the NJDEP Leeds Point Laboratory (NJDEP, 1997).

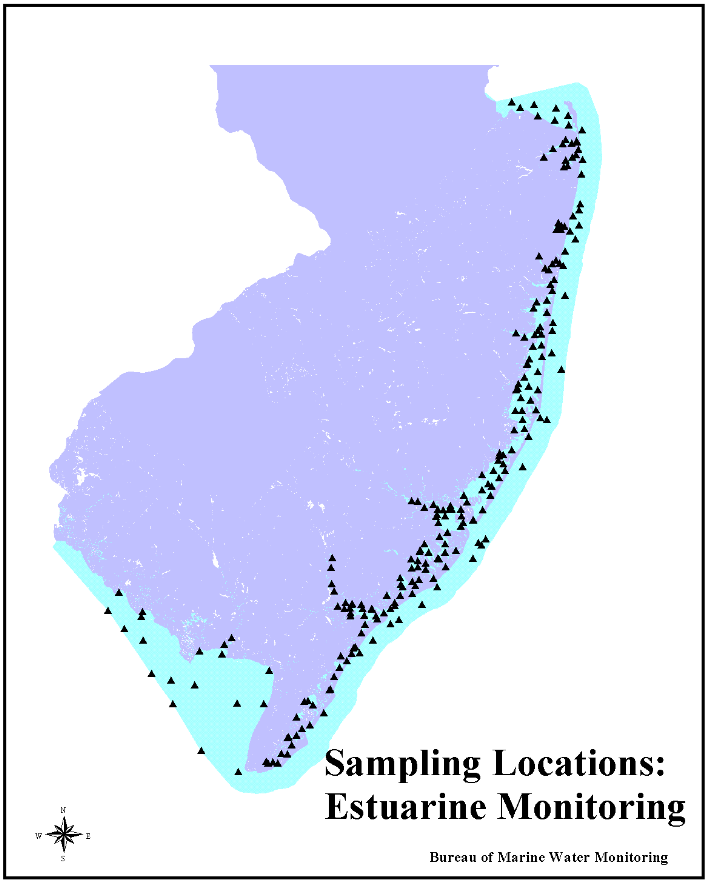


Figure 1: Sampling Locations

Table 1: Analytical Methods and Preservation

Parameter	Analytical Method		Preservation		Container Material	Holding Time
	Method	Reference	Method	Reference		
Salinity	2520.2	NJDEP 1989		Unesco, 1981		
Dissolved Oxygen	360.2	NJDEP 1989	P-4[2]	Std. Meth. 18th ed.		8 hrs
Total Suspended Solids	160.2	NJDEP 1989	P-1	USEPA 1979	PE	7 days
Ammonia	350.4	NJDEP 1989	Phenol	Parsons 1985	PP	2 weeks
Nitrate & Nitrite	353.2	NJDEP 1989	Freeze	Parsons 1985	PP	1 month
Orthophosphate	365.1	NJDEP 1989	Freeze	Parsons 1985	PP	1 month
Total Nitrogen	351.1	NJDEP 1989	Freeze	Parsons 1985	PP	1 month
Fecal Coliform Bacteria	31615	NJDEP 1989	P-1	NJDEP 1987	G	6 hrs

[1]Material Types: PE=polyethylene PP=polypropylene G=glass
[2]Preservation Method: P-4=alkaline iodide & manganous sulfate; P-1=store on ice; P-5=pH<2 with nitric acid; P10=store on ice with 80 mg/L sodium thiosulfate added.

Field Measurements

Station locations were identified in the field using GPS, LORAN C and radar at the ocean stations and by dead reckoning in the estuarine stations. Tide stage was calculated based on sample collection time using NOAA Tide Tables. Measurements made in the field were water temperature and Secchi depth.

Wet Chemistry Analyses

Salinity was measured by conductivity using a procedure based on the UNESCO practical salinity scale (UNESCO, 1981. See also APHA, 17th ed. 1989, 18th ed. 1992.).

All nutrient determinations were made using an AAII type of autoanalyzer system. References for each of these procedures are shown in Table I.

> **Ammonia** was measured colorimetrically by the phenate method.
>
> **Nitrate plus nitrite** was measured by the cadmium reduction method.
>
> **Total nitrogen** was determined by a persulfate oxidation in 125 mLErlenmeyer flasks followed by nitrate analysis.
>
> **Orthophosphate** was measured by ascorbic acid reduction.
>
> **Inorganic nitrogen to phosphorus ratios** was calculated using moles of nitrogen as ammonia, nitrate and nitrite to moles of phosphorus as orthophosphate.

Dissolved oxygen was measured using the azide modification of the Winkler titration. **Percent saturation** of dissolved oxygen was calculated according to APHA (17th ed. 1989, 18th ed. 1992.) using dissolved oxygen, temperature and salinity data.

Bacteriological Analyses

The majority of fecal coliform bacterial concentrations were analyzed by the A-1 method. However, the EC method was used periodically. Although both evaluations are listed in the raw data as the Most Probable Number (MPN) the geometric means for the A-1 data were used in the Statistical Summaries.

RESULTS

Overall Summary Statistics

An overall summary of the data is provided in Table 2. These statistics represent all the values obtained for all stations throughout the State's coastal waters for the period July 1, 1993 through June 30, 1997. For fecal coliform bacteria, ammonia, nitrate + nitrite, and orthophosphate, the minimum values represent the analytical detection limit for the parameter.

Table 2: Summary Statistics

Parameter	N	Minimum	Maximum
Temperature (°C)	241	0.5	31
Salinity (PPT)	241	0.03	34.5
Fecal Coliform MPN	209	<3	>2400
Dissolved Oxygen (% Saturation)	241	27%	243%
Ammonia (µg N/L)	223	2	650
Nitrate + Nitrite (µg N/L)	241	<2.2	1194
Orthophosphate (µg P/L)	241	<1.1	280
Inorganic N:P ratio	223	0.01:1	185:1

Summary by Parameter

Physical Parameters

Temperature. Summer water temperatures average between 20^o C and 30^o C throughout much of the coastal waters, while winter water temperatures average between 0^o C and 10^o C.

Salinity. Salinity tends to be somewhat lower (indicating a higher proportion of freshwater) further from the Atlantic Ocean and/or during periods of greater rainfall. Except for those areas that are further from the Ocean, the average salinity throughout much of the coastal waters ranges from 20 – 30 ppt. Since the salinity can significantly affect the species composition in estuarine waters, the salinity regime for each sampling point is an important component in understanding the complex ecological balance in coastal waters.

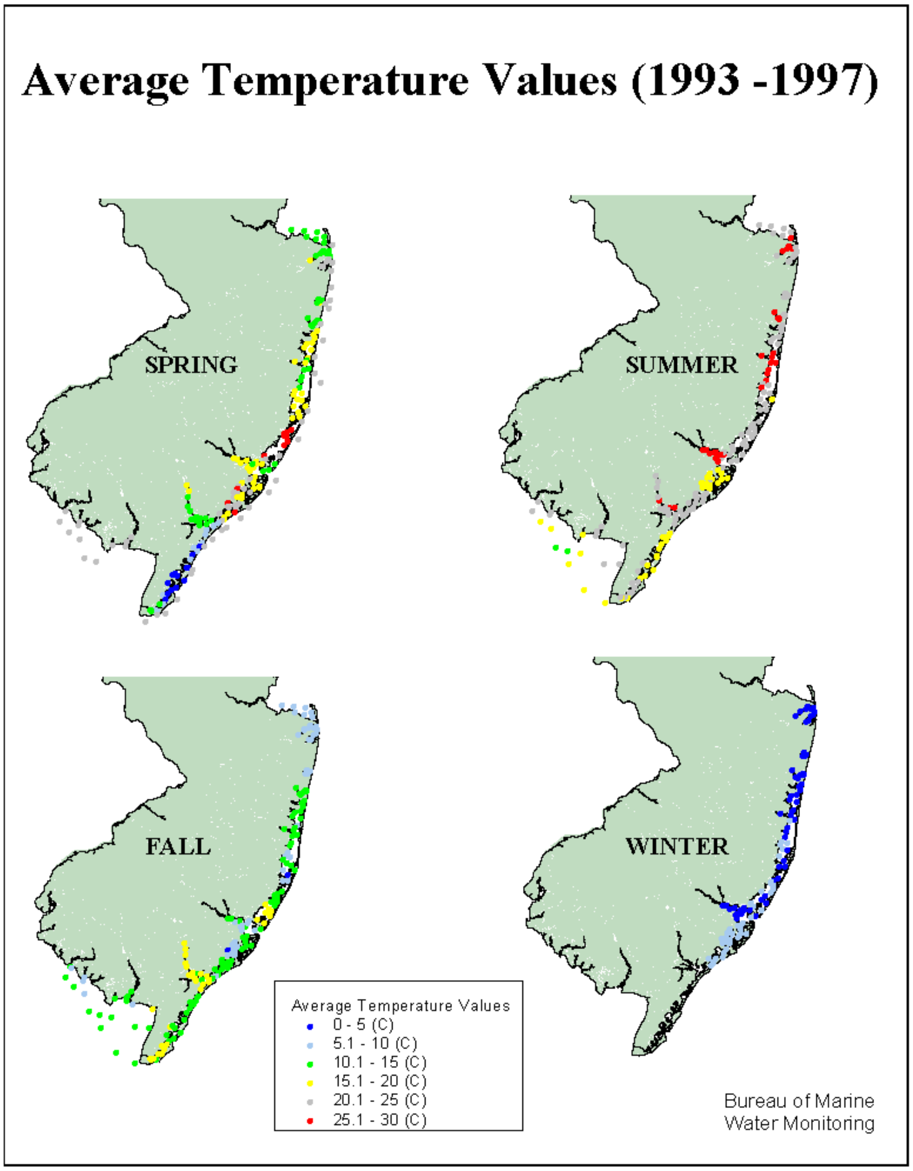


Figure 2: Temperature (1993 - 1997)

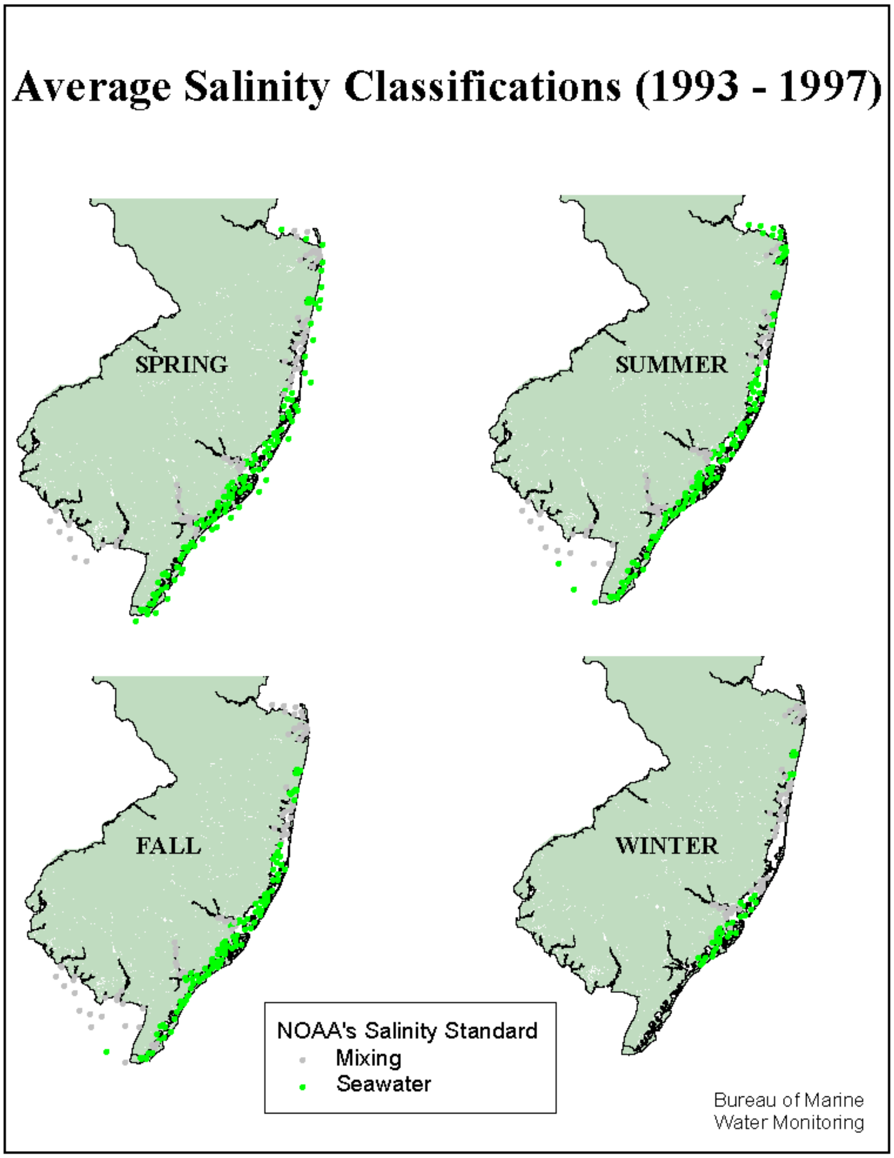


Figure 3: Salinity (1993 - 1997)

Secchi Depth. The measured Secchi Depth is an indicator of the relative turbidity of the water. When Secchi Depths are relatively low, less light penetrates the water column and is available as an energy source for photosynthesis. There are numerous factors that affect the turbidity, including sediment load from anthropomorphic sources and the concentration of algal cells in the water. In general, measured Secchi Depth tends to be somewhat higher in the winter (when the concentration of algal cells is diminished) and lower in the summer.

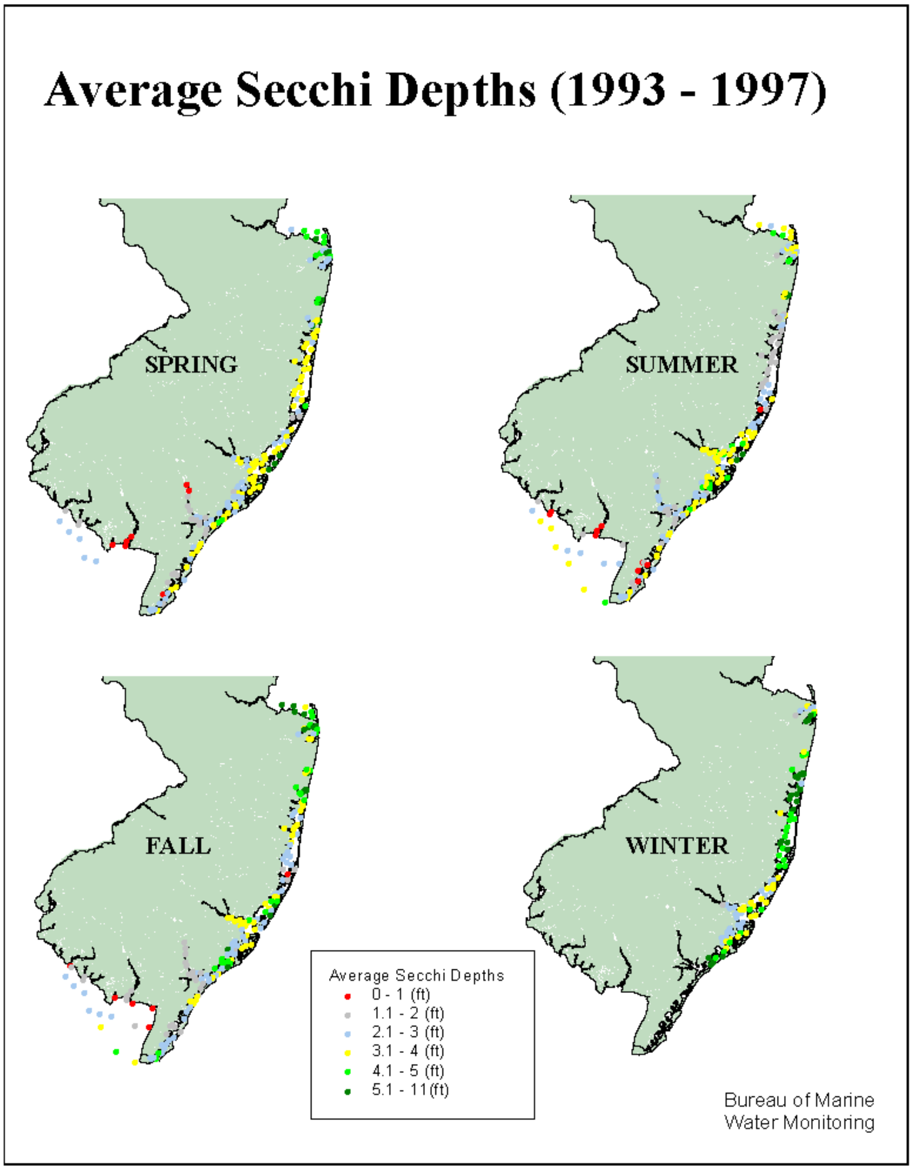


Figure 4: Secchi Depth (1993 - 1997)

Dissolved Oxygen

Dissolved oxygen data is shown below as both the seasonal average values and the seasonal minimum values. The average values provide an overall indicator of the relative concentration in the water column. The minimum values provide an indicator of the potential for biological stress due to insufficient oxygen levels in the water column. It should be noted that periods of low dissolved oxygen, even in the presence of acceptable average values, can result in hypoxia and death of organisms.

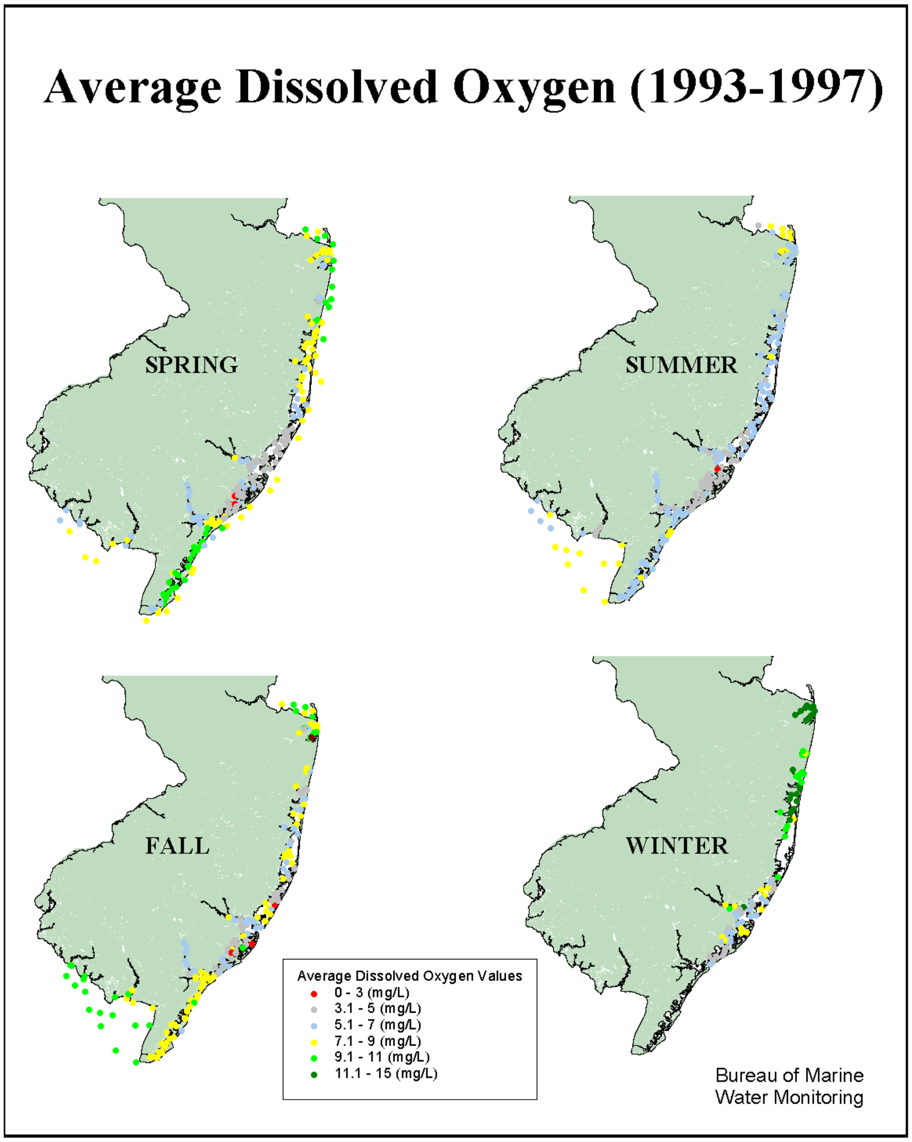


Figure 5: Average Dissolved Oxygen (1993 - 1997)

The average dissolved oxygen is highest in the winter months, particularly north of Barnegat Bay, while the lowest averages are generally observed during the summer in the back bays in Atlantic and Cape May Counties. This pattern is due to a combination of water temperature, water depth, and the rate of primary productivity.

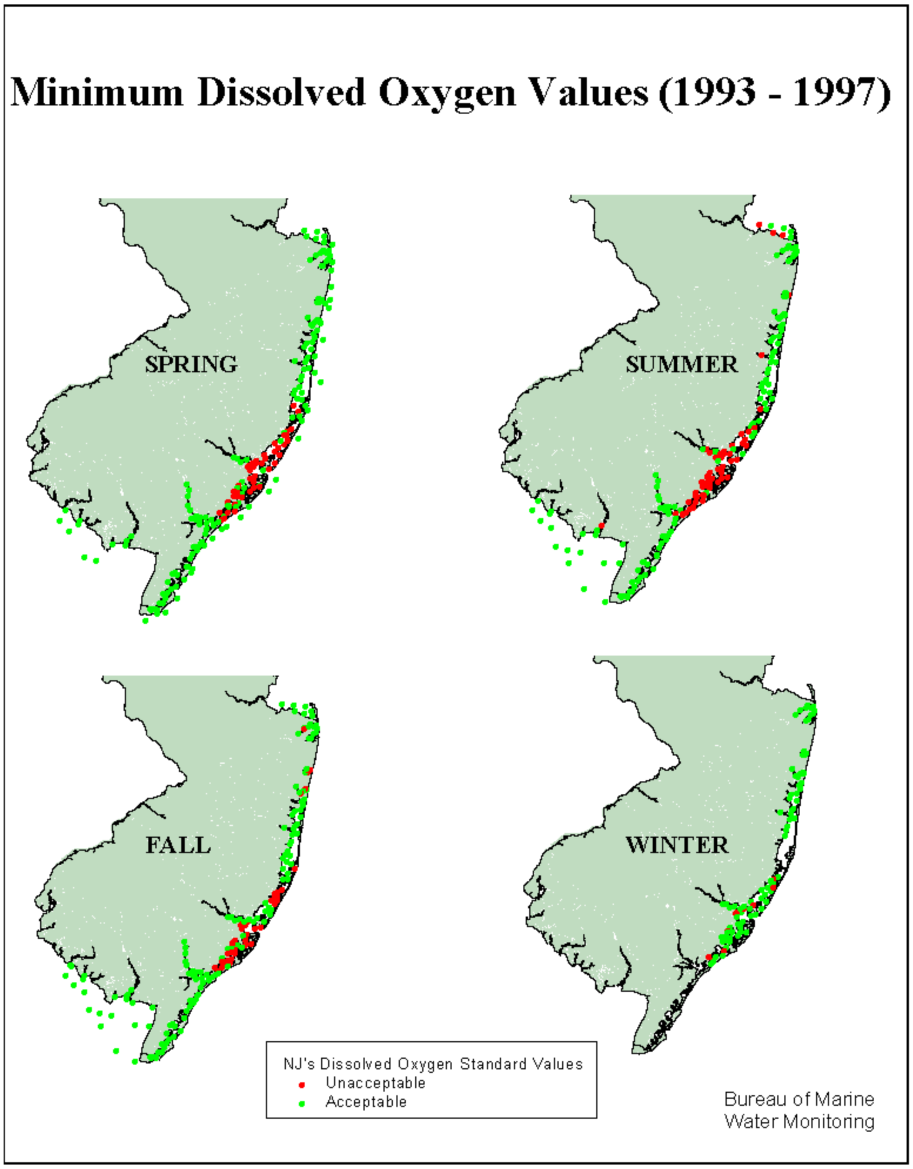


Figure 6: Minimum Dissolved Oxygen (1993 - 1997)

The minimum levels (red dots shown in the figure below) indicate those stations where the minimum measured level does not meet the minimum New Jersey water quality criteria of 4.0 mg/L. The density of those stations not meeting that criterion is highest during the summer months in southern Barnegat Bay and the back bays from Great Bay to Great Egg Harbor River. These areas tend to be shallow, so that the water warms quickly. Warm water has less capacity to dissolve oxygen, contributing to depletion of the oxygen.

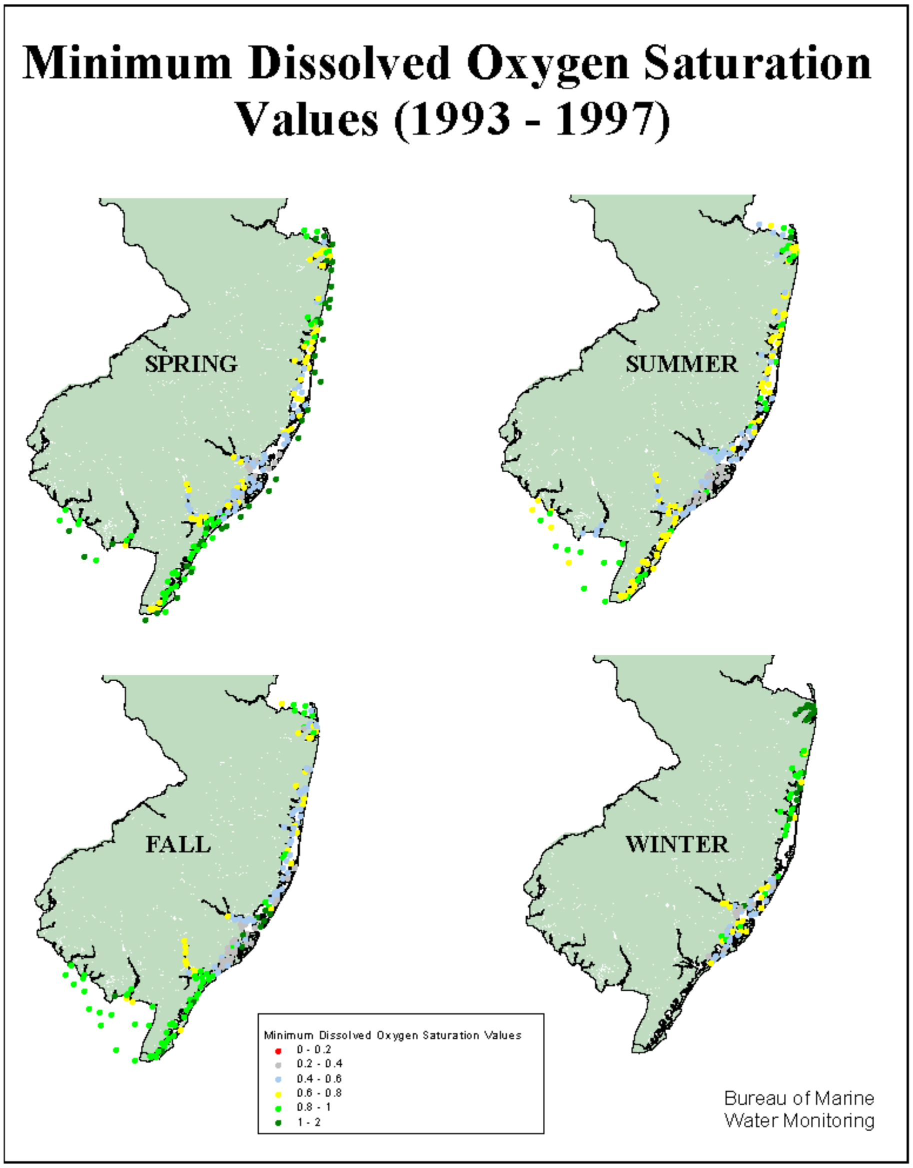


Figure 7: Dissolved Oxygen Percent Saturation (1993 - 1997)

Dissolved oxygen data must be evaluated in conjunction with temperature and salinity for each data point, since the solubility of oxygen in water is dependent on both salinity and temperature. The resulting value, % saturation, provides a better indicator of the relative amount of oxygen available to aquatic biota that only the concentration.

When the percent saturation values for the minimum dissolved oxygen are examined, the lowest values are shown during the summer through fall in the area from Great Bay to Great Egg Harbor. Low levels are also found in the nearshore areas of Delaware Bay. Supersaturated values are shown offshore during the spring season and in the Navesink and Shrewsbury Rivers during the winter.

Nutrients

Ammonia-N. The concentration of ammonia-N tend to be highest during the summer and fall in three discrete areas: the Raritan / Sandy Hook Bay / Navesink River / Shrewsbury River area, the back bays from Great Bay south to Great Egg Harbor River, and the nearshore areas of Delaware Bay.. These are the same areas with relatively low dissolved oxygen levels.

Nitrate-N / Nitrite-N. Concentrations of nitrate-N and nitrite-N tend to be relatively low, with the highest values found during the summer and fall in the nearshore areas of Delaware Bay.

Total Nitrogen. Total nitrogen includes the organic nitrogen component, which often results from the discharge of pollutants from anthropogenic sources. Organic nitrogen also results from high levels of algal growth, the decay of organic material, and related sources. The distribution of total nitrogen tends to parallel that of ammonia-N and nitrate-N / nitrite-N. Overall, average concentrations are highest in the summer and fall, with the highest levels measured in the nearshore regions of Delaware Bay, the back bays from Great Bay south to Great Egg Harbor River, and in the Raritan / Sandy Hook Bay and its tributaries. However, elevated levels are also found during the spring in these areas, and during the winter in the Navesink and Shrewsbury Rivers.

Orthophosphate-P. The highest levels of orthophosphate-P are measured during the summer in the Raritan / Sandy Hook Bay and its tributaries. Elevated levels are also found during the spring in the nearshore areas of Delaware Bay and during the summer in the back bays between Great Bay and Great Egg Harbor River.

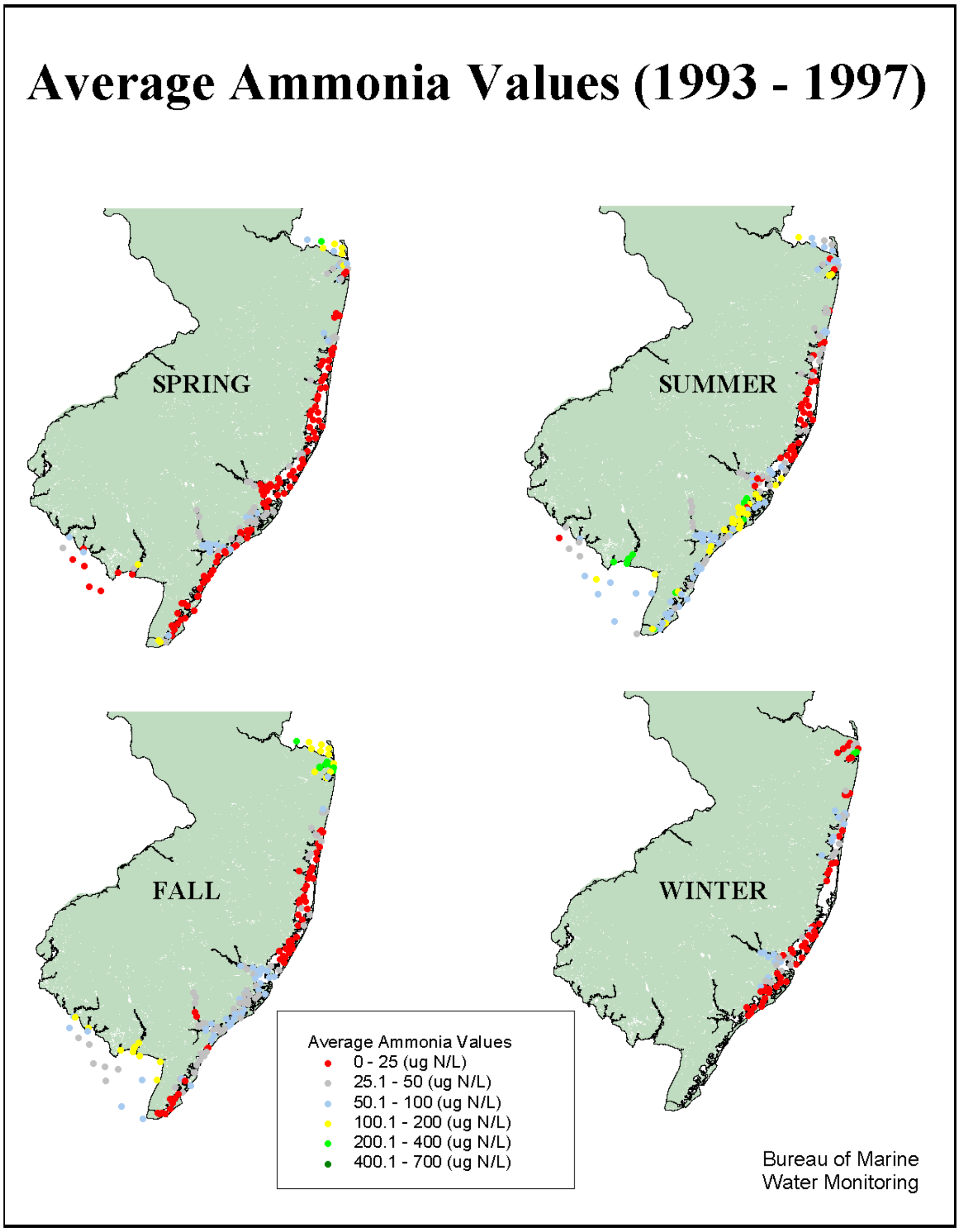
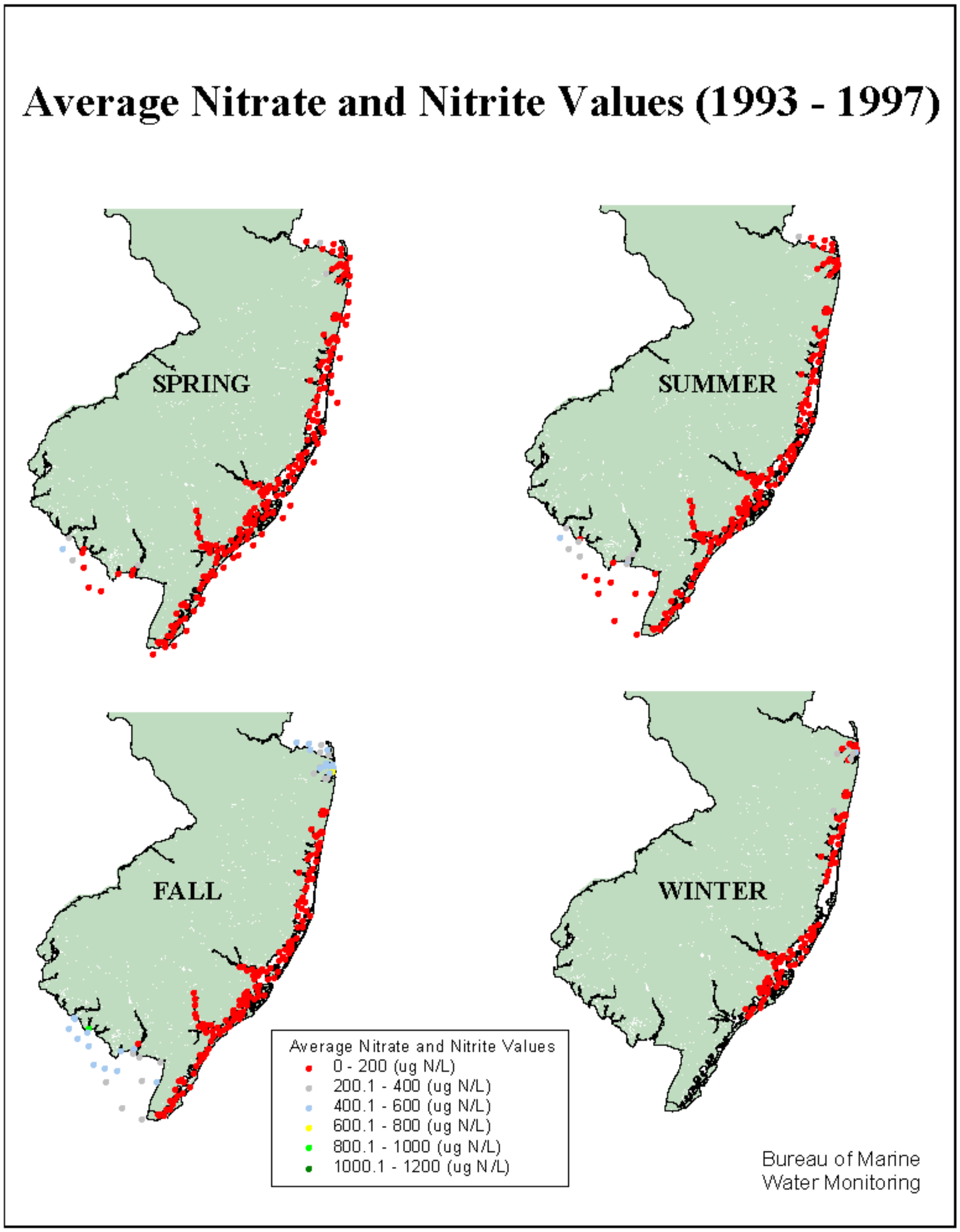


Figure 8: Average Ammonia Concentration (1993 - 1997)

Figure 9: Average Nitrate/Nitrite Concentration (1993 - 1997)



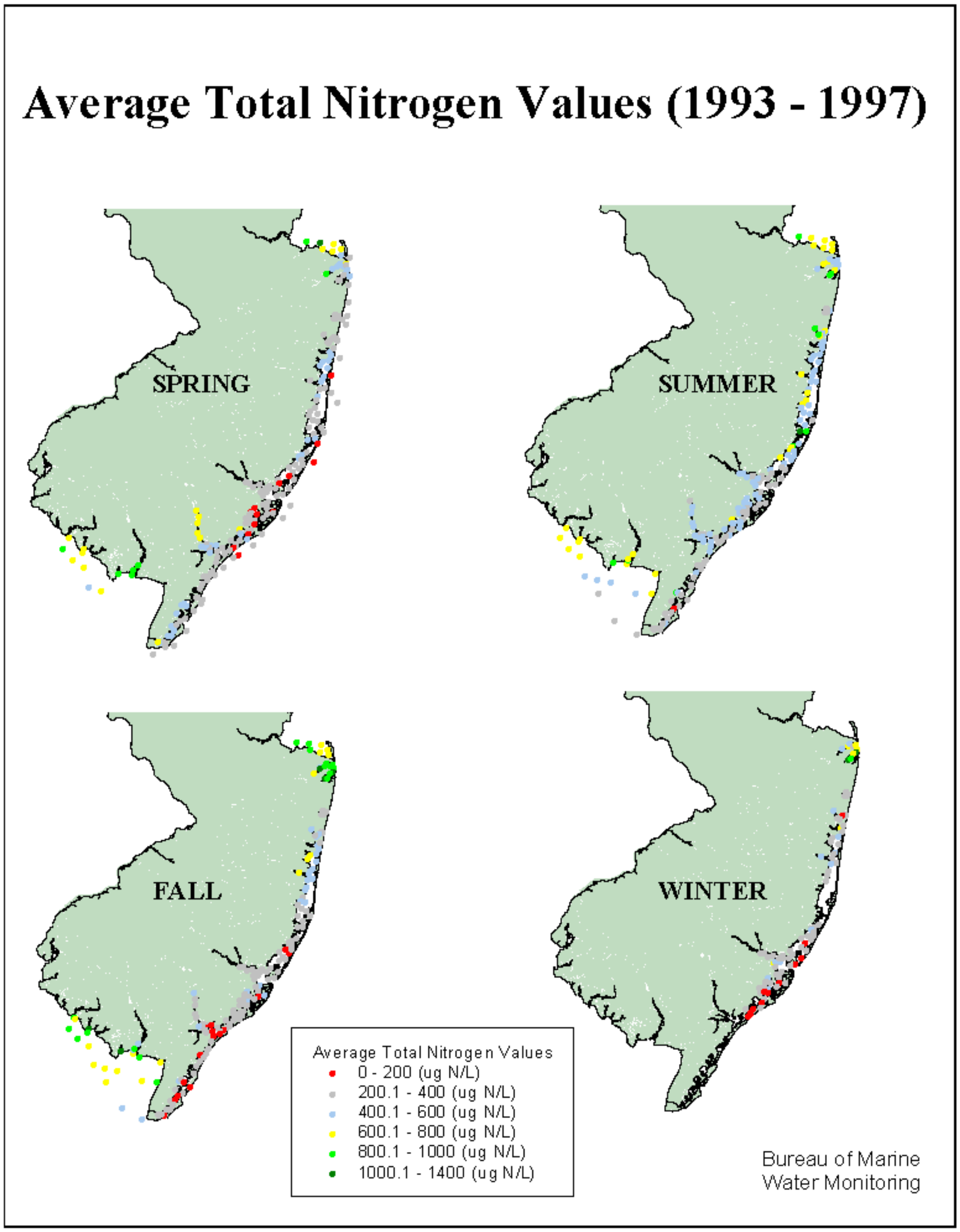


Figure 10: Average Total Nitrogen Concentration (1993 - 1997)

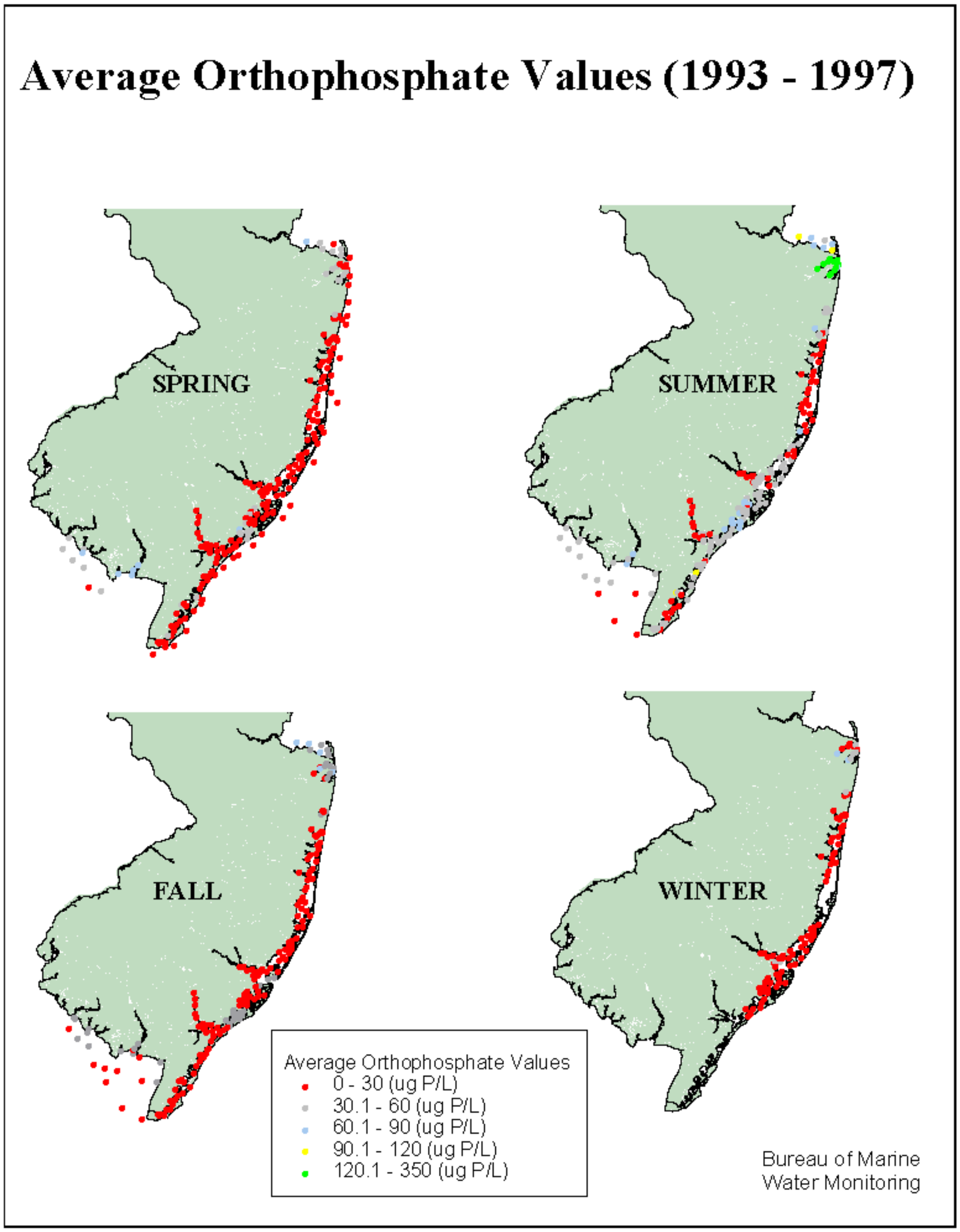


Figure 11: Average Orthophosphate Concentration (1993 - 1997)

Bacteriological Indicators

Fecal Coliform. All areas were in compliance with fecal coliform standards related to primary contact recreational uses (200 colonies / 100 mL). However, numerous areas did not meet the fecal coliform standard for shellfish harvest (14 MPN / 100 mL). (NOTE: The state of New Jersey does not use the fecal coliform standard for classifying shellfish waters for harvest – the total coliform standard is used for this purpose. All stations were in compliance with the applicable classification for the shellfish growing area.)

Areas where fecal coliform indicates a source of pollutants include all or portions of the following waterbodies:

- Monmouth County
    - Navesink River
    - Shark River
    - Manasquan River and Inlet
- Barnegat Bay
    - Metedeconk River
    - Toms River
    - Forked River
    - Silver Bay
    - Waretown Creek
    - Westecunk Creek
    - Mullica River
- Back Bays – Altantic and Cape May Counties
    - Absecon Creek
    - Great Egg Harbor River, Middle River
    - Beach Thorofare
    - Inside Thorofare
    - Lakes Bay
    - Jarvis Sound
    - Cape May Canal
- Delaware Bay
    - Maurice River and Cove
    - Nautuxent Cove

Each of these identified areas have impaired water quality as indicated by fecal coliform levels, dissolved oxygen levels, and nutrient concentrations.

Total Coliform. Total coliform levels are not measured in conjunction with this sampling program. However, there is a significant body of data addressing total coiform and the implications of measured levels on the safety of shellfish harvested from classified shellfish waters. These data is published by the NJDEP, Bureau of Marine Water Monitoring as a part of the classification process for shellfish waters. Recent data is available at the NJDEP web site and may be downloaded. The web address is: **http:/www.state.nj.us/dep/dsr/bmw/index.htm** .

Summary by Waterbody

Sampling stations were organized according to location (e.g. Great Bay, Navesink River, or Atlantic Ocean). These data have been summarized below for various parameters. A complete listing of all data collected for 1993 – 1997 is included in Appendix III.

Hudson/Raritan Estuary

Location

Raritan Bay and Sandy Hook Bay are part of the Hudson River/Raritan Bay Estuary. The drainage area for this estuary covers almost 22,000 square kilometers and receives water from portions of New Jersey, New York, Massachusetts and Connecticut. Average daily freshwater inflow rate is 6.53×10^7 cubic meters/day, which it receives primarily from the Hudson and Raritan Rivers. The estuary has a total volume of 3.51×10^9 cubic meters and averages 4.6 M in depth (NOAA, 1985).

The Navesink watershed drains 95 square miles of urban/suburban residential development and agricultural lands. This river joins with the Shrewsbury River before entering the Atlantic Ocean through Sandy Hook Bay. The Navesink estuary contains 2,290 acres of shellfish growing waters, which support substantial commercial densities of hard clams (*Mercenaria mercenaria*) and soft clams (*Mya arenaria*) (Scro, 1993). This estuary is one of only three estuaries in the state that have a significant soft clam population.

Sampling Locations

Sampling stations were located in the southeastern portion of the estuary from 1.6 km north of Conaskank Point eastward into Sandy Hook Bay. Due to weather and scheduling conflicts, samples were not collected during the autumn season in Raritan Bay and Sandy Hook Bay.

Sampling stations in the Navesink River were located from Red Bank to the confluence with the Shrewsbury River. Sampling stations in the Shrewsbury River were located from Little Silver to the confluence with Sandy Hook Bay.

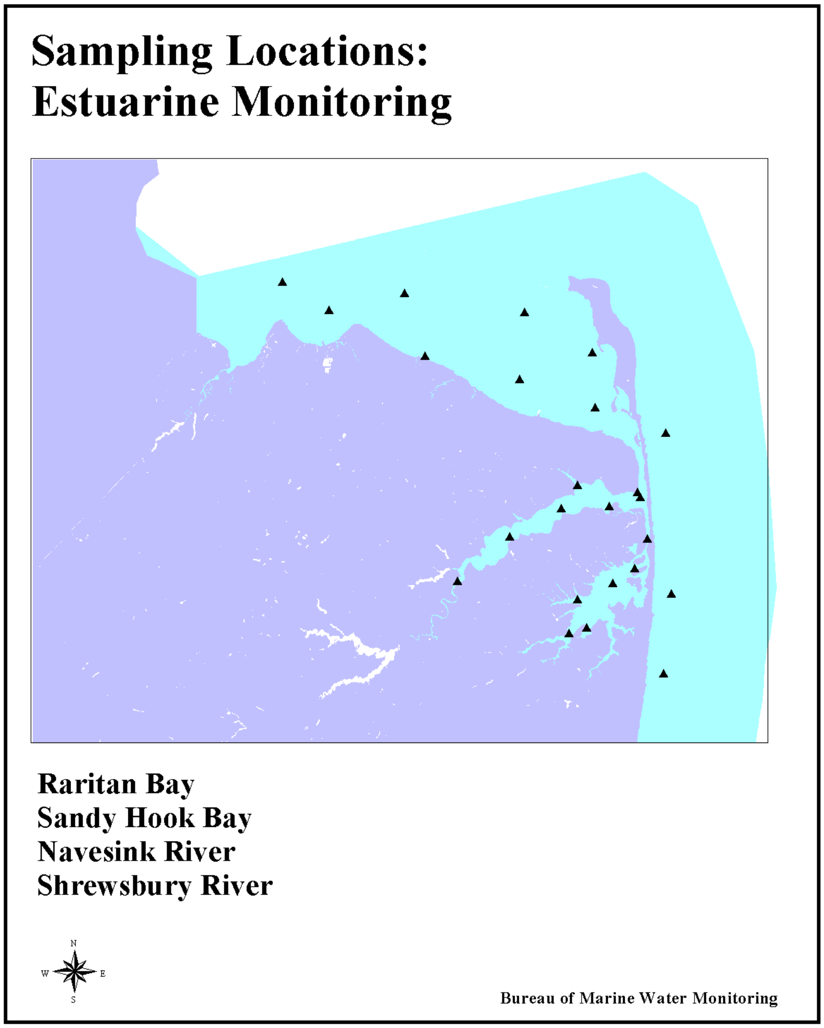


Figure 12: Raritan / Sandy Hook Bays Sampling Locations

Physical Parameters

The physical parameters of temperature, salinity, and Secchi depth are typical of what would be expected in an embayment close to the ocean, where oceanic influences dominate many physical parameters.

Temperature. Spring temperatures range from 10 – 15^{o} C, while summer temperatures range from 20 – 30^{o} C. Temperature during the fall tends to be less than 10^{o} C.

Salinity. Salinity throughout this area tends to be approximately 20 – 30^{o}/oo. The highest salinity is generally recorded during the summer when the stream flow and precipitation inputs are at a minimum.

Secchi Depth. Secchi depth tended to be greatest in spring and fall, with some values >5 feet. Summer values tended to be significantly less, with values as low as 2 feet.

Dissolved Oxygen

Water quality in this estuary was characterized by a frequent occurrence of oxygen supersaturation. This occurred in Raritan Bay and Sandy Hook Bay in the spring, summer, and fall and throughout the year in both the Navesink and Shrewsbury Rivers. Supersaturated values are more frequently measured in this estuary system than elsewhere in the State.

Dissolved oxygen levels tend to be highest during the winter when the water is colder and lowest in the summer when the water is warmer and biological activity is at a peak. There were occasional high dissolved oxygen values during the summer for samples obtained during the early morning, indicating the potential of a significant diurnal swing in dissolved oxygen levels. There were several sampling stations in the Raritan Bay where the surface water quality criterion (minimum 4.0 mg/L) for dissolved oxygen was not met during the summer. NOAA has described a slightly higher standard (minimum 5.0 mg/L) as indicative of waters that are biologically stressed. There were also several stations in the Navesink River, as well as additional stations in the Raritan Bay that failed to achieve the NOAA minimum dissolved oxygen standard during the summer.

Waterbody	Minimum mg/L	Maximum mg/L	Mean % saturation
Raritan / Sandy Hook Bay	3.4	10.95	95
Navesink River	3.65	13.6	87
Shrewsbury River	4.9	15	90

Table 3: Dissolved Oxygen – Raritan / Sandy Hook Bays, Navesink River, Shrewsbury River

Nutrients

The Raritan Bay and its tributaries are characterized by relatively nutrient rich waters. Levels of the various nitrogen species are highest in the spring and fall, and somewhat lower during the summer when various algal species assimilate the nutrients into algal biomass. Total nitrogen, which includes the organic component, peaks during summer to fall.

Waterbody	Minimum µg/L	Maximum µg/L	Mean µg/L
Ammonia-N			
Raritan / Sandy Hook Bay	5	391	120
Navesink River	7.09	276	88
Shrewsbury River	6.3	307	96
Nitrate-N / Nitrite-N			
Raritan / Sandy Hook Bay	7	685	222
Navesink River	4	579	144
Shrewsbury River	4	806	217
Total Nitrogen			
Raritan / Sandy Hook Bay	333	1048	750
Navesink River	222	1734	662
Shrewsbury River	235	1497	745
Orthophosphate-P			
Raritan / Sandy Hook Bay	13	155	64
Navesink River	13	280	93
Shrewsbury River	16	245	88

Table 4: Nutrients - Raritan / Sandy Hook Bays, Navesink River, Shrewsbury River

Bacteriological Indicators

Fecal coliform levels were consistent with the New Jersey water quality criteria (200 / 100 mL) for primary contact recreation (bathing beaches) at all stations. Water quality using this indicator was best closer to the ocean and most compromised in the upper estuary. In the Navesink and Shrewsbury Rivers, fecal coliform levels exceeded the standards for shellfish harvest at upstream stations and met the criteria at stations closer to the mouth of the river.

Barnegat Bay

Location

Barnegat Bay is a shallow, lagoon-type estuary with an average depth of approximately 1.5 M. It extends from Bay Head in the north to Little Egg Harbor in the south (Chizmadia *et al.*, 1984). It has a total volume of approximately 2.40×10^8 cubic meters and receives an average of 1.75×10^6 cubic meters/day of freshwater runoff (Durand, 1984).

Sampling Locations

There are 42 sampling stations distributed from the Metedeconk River in the north to Little Egg Harbor in the south. The location of these sampling stations is shown below.

Physical Parameters

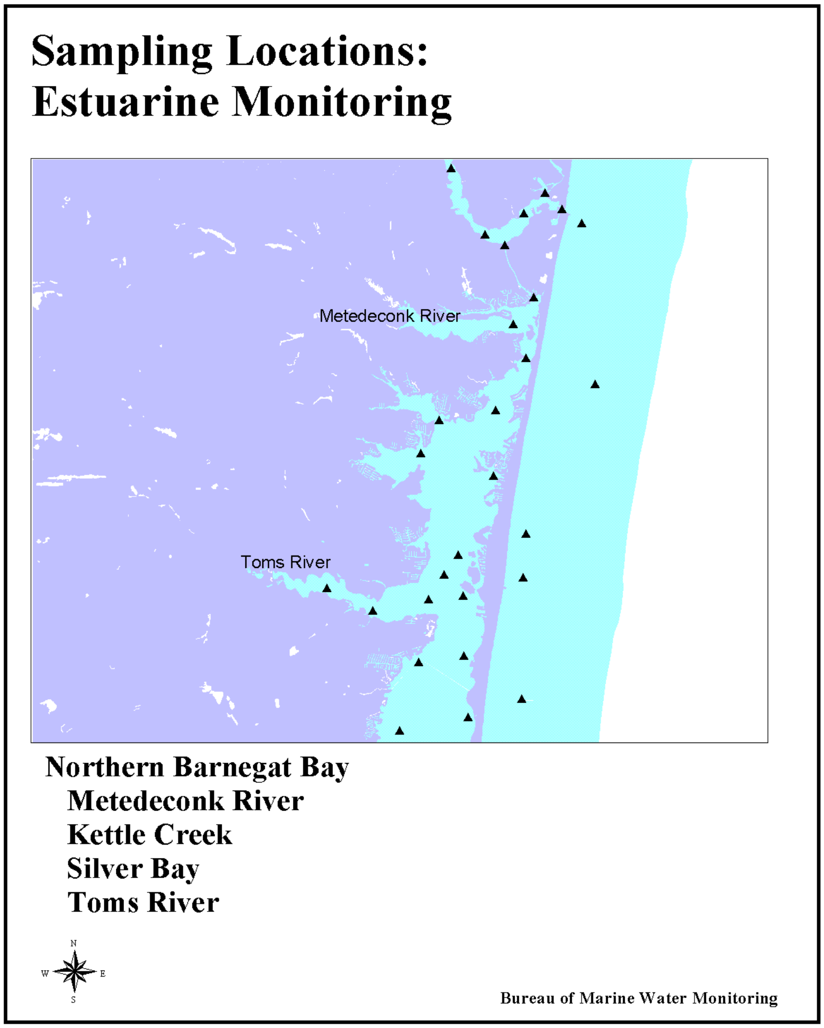
The physical parameters of temperature, salinity, and Secchi depth are typical of what would be expected in an embayment close to the ocean, where oceanic influences dominate many physical parameters.

Temperature. Spring temperatures range from 10 – 20^o C, while summer temperatures range from 20 – 30^o C. Temperature during the fall tends to be less than 15^o C.

Salinity. Salinity throughout this area ranges from 5 – 30^o/oo. The highest salinity is generally recorded during the summer when the stream flow and precipitation inputs are at a minimum. The lowest salinity is found in the northern section of the Bay (between the Metedeconk and Toms Rivers).

Secchi Depth. Secchi depth tended to be greatest in winter, with some values >5 feet. Summer values tended to be significantly less, with some values less than 1 foot.

Figure 13: Sampling Locations: Barnegat Bay



Dissolved Oxygen

Water quality in this estuary was characterized by a frequent occurrence of oxygen supersaturation in the northern section of the Bay during the winter. In contrast, very low oxygen values were measured throughout the year at several stations in the southern part of the Bay, particularly in Little Egg Harbor.

Dissolved oxygen levels tend to be highest during the winter when the water is colder and lowest in the summer when the water is warmer and biological activity is at a peak. There were occasional high dissolved oxygen values during the summer for samples obtained during the early morning, indicating the potential of a significant diurnal swing in dissolved oxygen levels. There were numerous sampling stations in Little Egg Harbor where the surface water quality criterion (minimum 4.0 mg/L) for dissolved oxygen was not met during the summer. The minimum measured value in Little Egg Harbor was 2.1 mg/L. NOAA has described a slightly higher standard (minimum 5.0 mg/L) as indicative of waters that are biologically stressed. There were several additional stations spread throughout the Bay that failed to achieve the NOAA minimum dissolved oxygen standard, particularly during the summer.

Waterbody	Minimum mg/L	Maximum mg/L	Mean % saturation
Barnegat Bay	3.4	12.8	82.9
Metedeconk River	5.7	13.1	60.8
Kettle Creek	4.9	12.1	83.5
Silver Bay	4.4	12.4	91.0
Toms River	3.05	11.5	82.8
Cedar Creek	5.0	10.2	76.7
Forked River	4.3	9.9	74.2
Oyster Creek	5.1	8.8	80.4
Manahawkin Bay	3.6	9.85	64.3
Little Egg Harbor	2.1	8.15	63.6

Table 5: Dissolved Oxygen - Barnegat Bay Area

Nutrients

Seasonal Patterns. There was no clear seasonal pattern in the concentration of nitrate / nitrite–N. Both ammonia-N and total nitrogen were higher in the summer. Total nitrogen was also elevated in the fall, while ammonia-N was also higher in the winter. Phosphorus levels were somewhat higher in the summer.

Spatial Distribution. Levels of all nutrient fractions were highest in the tributaries, particularly the tributaries north of Barnegat Inlet.

Proportion of Organic Nitrogen. The organic nitrogen fraction comprised up to approximately 95% of the nitrogen load in Barnegat Bay and Little Egg Harbor. In the tidal tributaries carrying a heavier nutrient load, the proportion of organic nitrogen was somewhat less, although the absolute concentration was significantly greater in those tidal tributaries. This pattern is consistent with data collected during earlier years.

Waterbody	Ammonia-N µg N/L	Nitrate / Nitrite - N µg N/L	Total Nitrogen µg N/L	Ortho-Phosphate µg P/L
Barnegat Bay	18.0	18.6	440.8	18.7

Metedeconk River	52.1	679.4	971.5	7.5
Kettle Creek	29.0	852.0	1030	6.2
Silver Bay	46.4	971.8	1799	3.3
Toms River	41.7	96.4	517.9	16.8
Cedar Creek	20.1	37.3	170.5	2.5
Forked River	20.4	33.3	230.7	3.1
Oyster Creek	12.0	10.5	194.3	2.0
Manahawkin Bay	16.2	8.7	498.0	17.6
Little Egg Harbor	27.0	15.2	337.8	21.1

Table 6: Nutrients – Barnegat Bay and Tidal Tributaries (Mean Value)

Bacteriological Indicators

Fecal coliform levels were consistent with the New Jersey water quality criteria (200 / 100 mL) for primary contact recreation (bathing beaches) at all stations. Water quality using this indicator was best closer to the ocean and most compromised in the upper estuary. In the tidal tributaries, fecal coliform levels exceeded the standards for unrestricted shellfish harvest. This more restrictive standard was also occasionally exceeded at stations adjacent to the barrier island.

Mullica River/Great Bay Estuary

Location

The Mullica River/Great Bay estuary is the most pristine in the State. It has a drainage area of 1474 km^2, which is principally undeveloped pinelands and agricultural land. It has a total volume of 4.00×10^7 cubic meters and on average receives 2.27×10^6 cubic meters/day of freshwater runoff. The Mullica River/Great Bay estuary has an average depth at mean low water of 1.7 M (Durand, 1984).

Sampling Locations

There are 13 sampling stations distributed in the Mullica River and Great Bay. The location of these sampling stations is shown below.

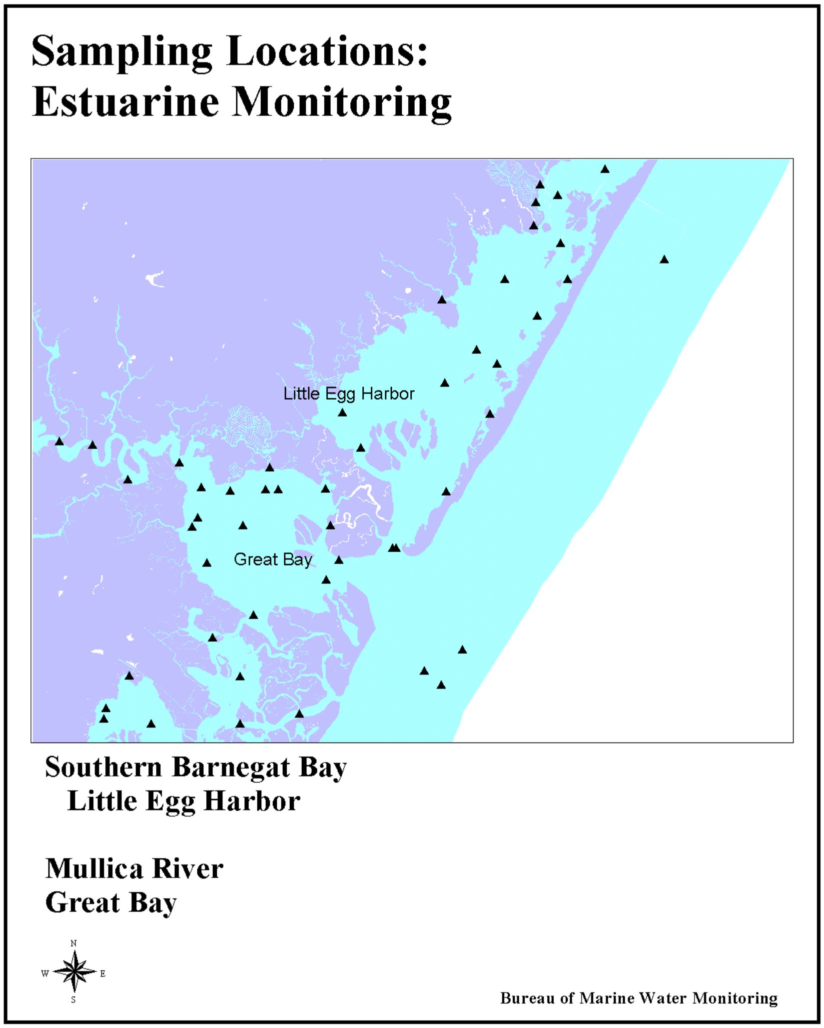


Figure 14: Sampling Locations: Southern Barnegat Bay, Mullica River, Great Bay

Physical Parameters

The physical parameters of temperature, salinity, and Secchi depth are typical of what would be expected in an embayment close to the ocean, where oceanic influences dominate many physical parameters, and an estuarine river.

Temperature. Spring temperatures range from 8 – 15° C, while summer temperatures range from 20 – 30° C. Temperature during the fall tends to be less than 15° C.

Salinity. Salinity throughout this area ranges from 5 – 30°/oo. The highest salinity is generally recorded during the summer when the stream flow and precipitation inputs are at a minimum. The lowest salinity is found in the western (most upgradient) section of the Mullica River.

Secchi Depth. Secchi depth tended to range from 1 – 4 feet. There is no significant seasonal component.

Dissolved Oxygen

Water quality in this estuary was characterized by a frequent occurrence of very low levels of oxygen in the Bay. There were numerous occurrences in Great Bay of dissolved oxygen levels significantly less than the minimum dissolved oxygen water quality standard.

Dissolved oxygen levels tend to be highest during the winter when the water is colder and lowest in the summer when the water is warmer and biological activity is at a peak. There were occasional high dissolved oxygen values during the summer for samples obtained during the early morning, indicating the potential of a significant diurnal swing in dissolved oxygen levels. There were also several stations that generally met the state minimum standard, but failed to achieve the NOAA minimum dissolved oxygen standard.

Waterbody	**Minimum** mg/L	**Maximum** mg/L	**Mean** % saturation
Mullica River	3.6	10.1	67.2
Great Bay	2.5	9.7	57.9

Table 7: Dissolved Oxygen - Mullica River and Great Bay

Nutrients

Seasonal Patterns. There was no clear seasonal pattern in the concentration of nitrate / nitrite–N. Ammonia-N was higher in the fall and winter. Total nitrogen was elevated in the summer. Phosphorus levels were somewhat higher in the summer.

Spatial Distribution. Levels of all nutrient fractions were approximately the same throughout the River and Bay.

Proportion of Organic Nitrogen. The organic nitrogen fraction comprised approximately 80% of the nitrogen load. This pattern is consistent with data collected during earlier years.

Table 8: Nutrients - Mullica River and Great Bay

Waterbody	**Ammonia-N** µg N/L	**Nitrate / Nitrite - N** µg N/L	**Total Nitrogen** µg N/L	**Ortho-Phosphate** µg P/L
Mullica River	46.6	29.7	354.7	19.5
Great Bay	38.7	29.9	354.3	24.5

Bacteriological Indicators

Fecal coliform levels were consistent with the New Jersey water quality criteria (200 / 100 mL) for primary contact recreation (bathing beaches) at all stations. Water quality using this indicator was best closer to the ocean and most compromised in the upper estuary, where there were occasional high scores. On 8/3/93 and 8/2/94, many stations had high coliform counts; some of those individaul levels exceeded the bathing beach standard. Stations in Great Bay met the standards for unrestricted shellfish harvest, while stations in the Mullica River sometimes met this more restrictive standard.

Back Bays – Great Bay to Great Egg Harbor River

Location

There are 5 small bays located between Great Bay (on the north) and Great Egg Harbor Bay (on the south). These include three small bays (Little Bay, Reed Bay, and Absecon Bay) that drain to Absecon Inlet and two (Lakes Bay and Scull Bay) that drain to Great Egg Harbor Inlet. Each of these small bays is very shallow, with no significant freshwater input from a river or large stream.

Sampling Locations

There are 26 sampling stations distributed from Little Bay in the north to Scull Bay in the south. The location of these sampling stations is shown in Figure 15.

Physical Parameters

The physical parameters of temperature, salinity, and Secchi depth are typical of what would be expected in small shallow bays.

Temperature. Spring temperatures range from 10 – 20^{o} C, while summer temperatures range from 20 – 30^{o} C. Temperature during the fall tends to be close to 15^{o} C.

Salinity. Salinity throughout this area ranges from 15 – 32^{o}/oo, with few readings less than 20^{o}/oo reflecting the influence of the ocean on the dynamics within the bays.

Secchi Depth. Secchi depth tended to range from 2 – 5 feet, with minimal seasonal variation with a specific station.

Dissolved Oxygen

Water quality in this estuary was characterized by a frequent occurrence of very low levels of oxygen in the bays. There were numerous occurrences throughout the area of dissolved oxygen levels significantly less than the minimum dissolved oxygen water quality standard.

Dissolved oxygen levels tend to be highest during the winter when the water is colder and lowest in the summer when the water is warmer and biological activity is at a peak. Measured dissolved oxygen levels at numerous stations were significantly less than the minimum state standard. Most values were also less than the NOAA minimum dissolved oxygen standard. The NOAA standard is frequently used to identify waters that are biologically stressed by low levels of dissolved oxygen.

Waterbody	**Minimum** mg/L	**Maximum** mg/L	**Mean** % saturation
Little Bay	2.5	9.3	57.7
Reed Bay	2.3	6.45	50.6
Absecon Bay	2.7	7.8	51.8
Lakes Bay	2.35	9.9	59.9
Scull Bay	2.5	4.8	54.3

Table 9: Dissolved Oxygen – Back Bays

Nutrients

Seasonal Patterns. There was no clear seasonal pattern in the concentration of nitrate / nitrite–N. Ammonia-N, total nitrogen, and phosphorus were higher in the summer.

Spatial Distribution. There was a tendency for Little Bay to have slightly lower concentrations of nutrients than the other bays.

Proportion of Organic Nitrogen. The organic nitrogen fraction comprised up to approximately 80% of the nitrogen load in Little Bay, but only 65% of the load in Reed Bay and Absecon Bay.

Waterbody	**Ammonia-N** µg N/L	**Nitrate / Nitrite - N** µg N/L	**Total Nitrogen** µg N/L	**Ortho-Phosphate** µg P/L
Little Bay	51.2	21.3	330.6	26.2
Reed Bay	98.8	28.5	385.9	35.9
Absecon Bay	75.6	21.8	305.7	32.9
Lakes Bay	64.3	36.6	393.3	47.5
Scull Bay	74.1	32.8	379.0	37.0

Table 10: Nutrients – Back Bays (Mean Value)

Bacteriological Indicators

Fecal coliform levels were consistent with the New Jersey water quality criteria (200 / 100 mL) for primary contact recreation (bathing beaches) at all stations in Little Bay, Reed Bay, Absecon Bay, and Scull Bay. Several stations in Lakes Bay showed excursions above the bathing beach standard. In Absecon Bay and Lakes Bay, fecal coliform levels exceeded the standards for unrestricted shellfish harvest. This more restrictive standard was also occasionally exceeded at stations scattered throughout the area.

Great Egg Estuary

Location

The Great Egg estuary consists of the Great Egg, Tuckahoe and Middle Rivers and the Great Egg Harbor. Patcong Creek also contributes to the estuary. The drainage area of the estuary is roughly 1238 km^2. It has a total volume of 2.00×10^7 cubic meters and receives an average of 1.78×10^6 cubic meters/day of freshwater runoff. It is a relatively shallow estuary averaging 1.10 M in depth.

Sampling Locations

There are 20 sampling stations distributed throughout the Great Egg Harbor Estuary. The location of these sampling stations is shown below.

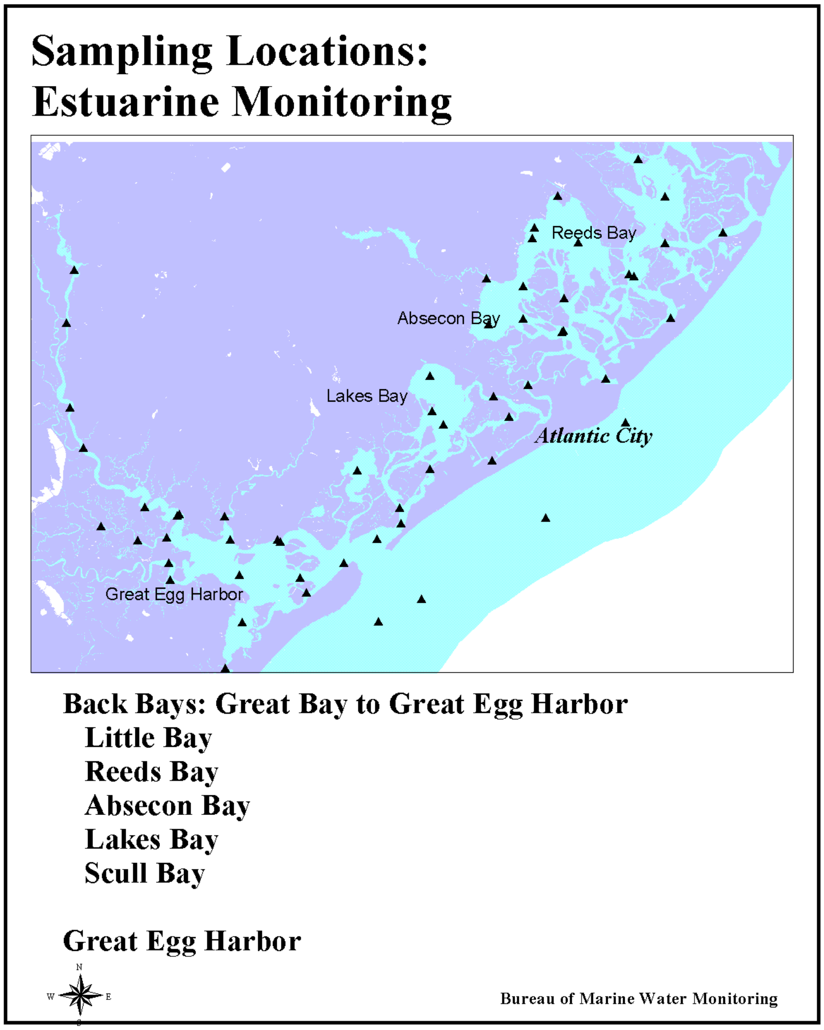


Figure 15: Sampling Locations: Great Egg Harbor River Estuary

Physical Parameters

The physical parameters of temperature, salinity, and Secchi depth are typical of what would be expected in an embayment close to the ocean, where oceanic influences dominate many physical parameters, and an estuarine river.

Temperature. Spring temperatures range from 8 – 15^{o} C, while summer temperatures range from 20 – 30^{o} C. Temperature during the fall tends to be less than 15^{o} C.

Salinity. Salinity throughout this area ranges from <1 – 30^{o}/oo. The highest salinity is generally recorded during the summer when the stream flow and precipitation inputs are at a minimum. The lowest salinity is found in the western (most upgradient) section of the Egg Harbor River.

Secchi Depth. Secchi depth tended to range from 1 – 4 feet. There is no significant seasonal component. The water tended to be somewhat clearer in the inlet, with lower secchi depths recorded in upstream areas.

Dissolved Oxygen

Water quality in this estuary was characterized by a frequent occurrence of very low levels of oxygen in the Bay. There were numerous occurrences of dissolved oxygen levels significantly less than the minimum dissolved oxygen water quality standard.

Dissolved oxygen levels tend to be highest during the winter when the water is colder and lowest in the summer when the water is warmer and biological activity is at a peak. There were occasional high dissolved oxygen values during the summer for samples obtained during the early morning, indicating the potential of a significant diurnal swing in dissolved oxygen levels. There were also several stations that generally met the state minimum standard, but failed to achieve the NOAA minimum dissolved oxygen standard.

Waterbody	Minimum mg/L	Maximum mg/L	Mean % saturation
Great Egg Harbor	2.8	8.3	82.0
Great Egg Harbor River	4	7.4	71.5
Tuckahoe River	4.5	7.7	76.5
Middle River	4.4	6.8	65.1
Patcong Creek	4.7	7.6	73.9

Table 11: Dissolved Oxygen - Great Egg Harbor River Estuary

Nutrients

Seasonal Patterns. There was no clear seasonal pattern in the concentration ammonia-N or of nitrate / nitrite–N. Total nitrogen and phosphorus were higher in the summer.

Spatial Distribution. Levels of all nutrient fractions were approximately the same throughout the estuary, except that levels of ammonia-N in the Tuckahoe River were higher than elsewhere.

Proportion of Organic Nitrogen. The organic nitrogen fraction comprised approximately 75% of the nitrogen load for the Bay, Great Egg River, and Patcong Creek. The ammonia-N fraction in the Tuckahoe River was significantly higher, so that the proportion of organic nitrogen was reduced to about 60%. For Middle River, the proportion of organic nitrogen was approximately 80%. This pattern is consistent with data collected during earlier years.

Waterbody	Ammonia-N µg N/L	Nitrate / Nitrite - N µg N/L	Total Nitrogen µg N/L	Ortho-Phosphate µg P/L
Great Egg Harbor	52.6	25.0	330.3	29.5
Great Egg Harbor River	70.9	26.3	375.3	28.0
Tuckahoe River	114.6	29.5	362.3	28.3
Middle River	67.1	22.1	420.9	19.7
Patcong Creek	70.1	22.9	379.5	23.9

Table 12: Nutrients - Great Egg Harbor River Estuary

Bacteriological Indicators

Fecal coliform levels in the Bay were consistent with the New Jersey water quality criteria (200 / 100 mL) for primary contact recreation (bathing beaches). Fecal coliform levels in the rivers generally exceeded the bathing beach criteria. Water quality using this indicator was best closer to the ocean and most compromised in the upper estuary. Stations in Great Egg Harbor River Bay generally also met the standards for unrestricted shellfish harvest.

Delaware Estuary

Location

The Delaware Estuary has a drainage area of roughly 12,000 km^2, which covers parts of New Jersey, Pennsylvania, Delaware and Maryland. It has a total volume of 1.47×10^{10} cubic meters and an average depth of 7.38 M. Average freshwater inflow from runoff is 4.84×10^{7} cubic meters/day.

Sampling Locations

There are 20 sampling stations along the axis of Delaware Estuary from Ship John Shoal to Cape May Point and east of the axis into the New Jersey side of the bay. In addition to the Bay, samples were obtained in the Maurice River, Dennis Creek, Maurice River Cove, Nantuxent Cove, and Cohansey Cove. The location of these sampling stations is shown below.

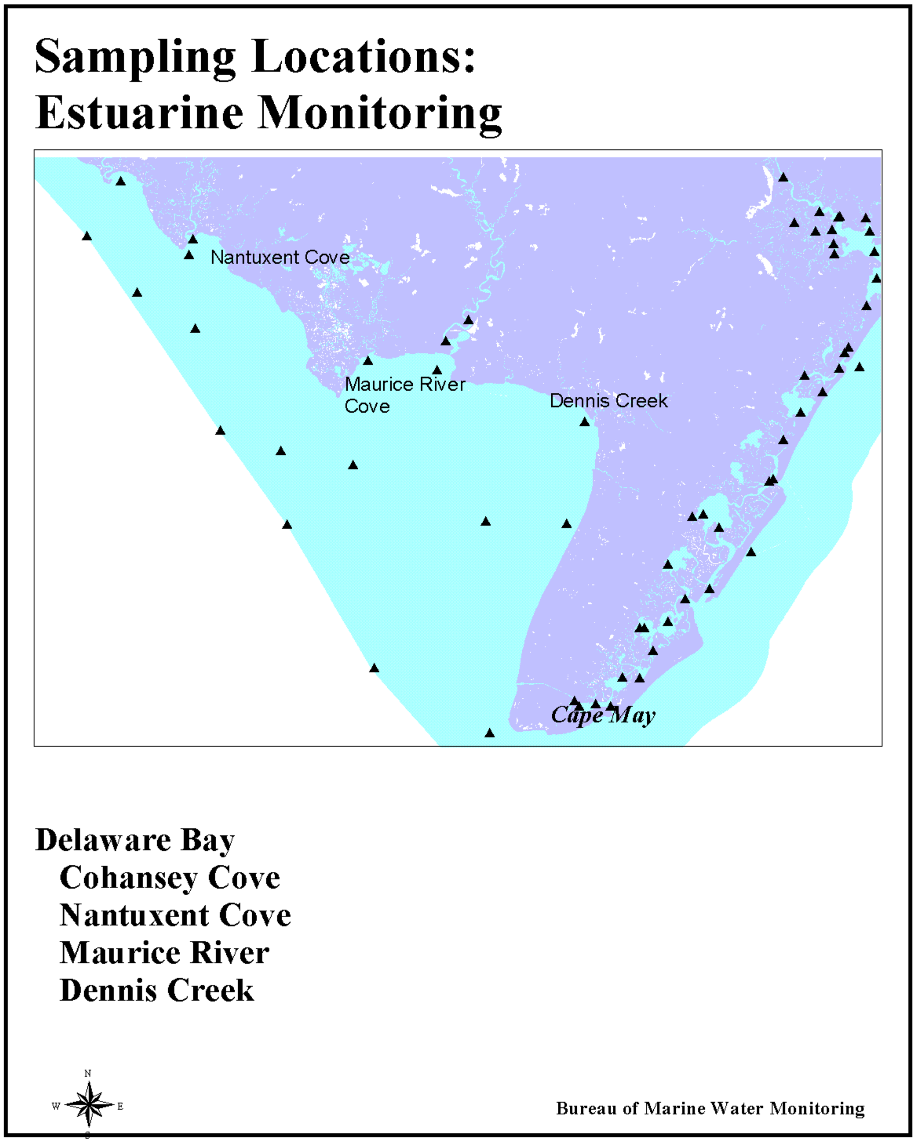


Figure 16: Sampling Locations: Delaware Bay & Southern Back Bays

Physical Parameters

The physical parameters of temperature, salinity, and Secchi depth are typical of what would be expected in a large open bay, where oceanic influences dominate many physical parameters close to the ocean and riverine factors dominate processes in upgradient regions.

Temperature. Spring temperatures range from 10 – 20^o C, while summer temperatures range from 20 – 25^o C. Temperature during the fall tends to be near 15^o C.

Salinity. Salinity throughout this area ranges from 10 – 30^o/oo. The highest salinity is generally recorded during the summer when the stream flow and precipitation inputs are at a minimum. The lowest salinity is found in the tidal tributaries.

Secchi Depth. Secchi depth tended to be greatest in winter, with some values between 4 - 5 feet. Summer values tended to be less, with some values < 1 foot. Many stations did not show a seasonal component to secchi depth, but had consistent measurements throughout the sampling period.

Dissolved Oxygen

Water quality in this estuary was characterized by a frequent occurrence of oxygen supersaturation during the summer.

Dissolved oxygen levels tend to be highest during the winter when the water is colder and lowest in the summer when the water is warmer and biological activity is at a peak. There were numerous high dissolved oxygen values during the summer for samples obtained during the early morning, indicating the potential of a significant diurnal swing in dissolved oxygen levels. There was a single sampling date when the surface water quality criterion (minimum 4.0 mg/L) for dissolved oxygen was not met during the summer. NOAA has described a slightly higher standard (minimum 5.0 mg/L) as indicative of waters that are biologically stressed. There were several additional stations spread throughout the Bay that occasionally failed to achieve the NOAA minimum dissolved oxygen standard, particularly during the summer.

Waterbody	Minimum mg/L	Maximum mg/L	Mean % saturation
Delaware Bay	6.3	10.6	96.0
Cohansey Cove	6.4	10.5	89.1
Nantuxent Cove	5.5	10.5	89.8
Maurice River	3.9	10.5	75.8
Maurice River Cove	4.4	10.7	76.3
Dennis Creek	6.2	9.2	98.9

Table 13: Dissolved Oxygen - Delaware Bay Area

Nutrients

Seasonal Patterns. Both ammonia-N and phosphorus were higher in the summer. Total nitrogen and nitrate-N were elevated in the fall.

Spatial Distribution. Levels of all nutrient fractions were highest closest to the shoreline, indicating that anthropogenic activities are a likely significant contributor to the excess nutrient load in the Bay.

Proportion of Organic Nitrogen. The organic nitrogen fraction comprised approximately 30 - 60% of the nitrogen load in Delaware Bay. The lowest proportion was in the Maurice River

(31%), while the highest proportion was in Dennis Creek (62%). Nutrient dynamics in the Delaware Bay are dominated by the presence of excess nitrate-N and, to a lesser extent, ammonia-N. This pattern is consistent with data collected during earlier years.

Waterbody	Ammonia-N µg N/L	Nitrate / Nitrite - N µg N/L	Total Nitrogen µg N/L	Ortho-Phosphate µg P/L
Delaware Bay	58.3	301.4	641.4	32.1
Cohansey Cove	54.8	354.0	687.4	48.3
Nantuxent Cove	63.5	392.5	878.8	46.0
Maurice River	204.5	257.1	735.6	58.7
Maurice River Cove	191.1	248.3	883.3	58.3
Dennis Creek	161.7	106.1	710.3	46.9

Table 14: Nutrients – Delaware Bay (Mean Value)

Bacteriological Indicators

Fecal coliform levels were consistent with the New Jersey water quality criteria (200 / 100 mL) for primary contact recreation (bathing beaches) at all stations, except those in the Maurice River and Maurice River Cove. Throughout most of the Bay, fecal coliform levels achieved the standards for unrestricted shellfish harvest. This more restrictive standard was occasionally exceeded at stations adjacent to the shoreline.

Atlantic Ocean

Sampling in the Atlantic Ocean was confined to the near-shore area (less than 3 miles from the coastline). A total of 29 ocean stations are included in the nutrient sampling network. This proximity to the coastline is reflected in the salinity values for these stations, which ranged from 24.8 PPT to 36.0 PPT and averaged 30.0 PPT.

Ocean samples were only collected once (on 6/26/1997). Therefore, evaluation of seasonal trends in the ocean data is not possible.

In addition, comparisons to other water bodies discussed in this study are not meaningful, except for fecal coliform bacteria. Overall, fecal coliform bacteria concentrations in the ocean stations were lower than any other body of water described in this report (geometric mean of less than 3.0 /100 mL). Only one sample had a bacteria concentration higher than the detection limit and that was 6.1 /100 mL. As a consequence all samples met the acceptable criteria for New Jersey's fecal coliform standard.

Additional sampling dates should be scheduled in subsequent years.

Summary by Waterbody Type and Season

Each location was grouped according to a modification of a classification scheme described by Boynton et al. (1982). Boynton compared 63 estuaries and developed a classification scheme based on factors that influence phytoplankton productivity. These categories were:

- River dominated estuaries
- Lagoons (estuarine waters that are shallow and well mixed)
- Embayments
- Fjords.

New Jersey's estuarine waters are included in two of these categories: river dominated estuaries and lagoons.

For the purpose of this study, five categories were added that are appropriate for New Jersey waters. These were

- River
- Tidal tributary
- Inlet
- Ocean
- Ocean near a sanitary discharge

Stations designated as river stations were locations where salinity values were consistently below 10 PPT.

The seasonal periods were designated as follows:

Summer: July 1 through September 30
Autumn: October 1 through December 31
Winter: January 1 through March 31
Spring: April 1 through June 30

Tables 3 - 9 provide summaries of average levels for each parameter with the sampling stations grouped by these waterbody classification categories as well as by season. The seasons were included to facilitate evaluation of seasonal trends.

River Dominated Estuaries

River dominated estuaries are those estuaries where the salinity is generally less than 25 PPT. In general, compared to the other types of waterbodies evaluated for this report, the dissolved oxygen (% saturation) is higher (80-90% saturation). The N:P ratio tends to be relatively low, indicating the potential for these river dominated estuaries to be nitrogen-limited. However, there are relatively high absolute concentrations of both nitrogen and phosphorus, particularly in the biologically available fractions.

Table 15: Estuarine – River Dominated Averages

Estuarine – River Dominated	Spring	Summer	Fall	Winter
Temperature (^{o}C)	16.1	23.4	10.1	3.5
Salinity (PPT)	19.0	23.1	20.6	17.8
Secchi Depth (feet)	3.5	2.9	3.7	4.4
Suspended Solids (mg/L)		38.7		
Dissolved Oxygen % Saturation)	82.9	85.3	83.9	93.0
Ammonia (μg N/L)	64.9	73.1	110.5	64.1
Nitrate + Nitrite (μg N/L)	82.3	88.1	360.9	175.1
Orthophosphate (μg P/L)	33.7	77.2	36.2	28.7
Organic Nitrogen	565.3	584.7	718.4	574.1
Inorganic N:P ratio	9.2	3.4	14.0	10.0
Fecal Coliform MPN (geometric mean)	8.0	12.5	7.4	6.8

Lagoons – Shallow Estuaries

These estuaries are relatively shallow and well-mixed, but with the higher salinity indicative of the influence of the ocean. In general, compared to the other estuary types, the dissolved oxygen (% saturation) tends to be lower (65-75 % saturation), perhaps as a result of shallow water being more easily warmed through solar heating. The N:P ratios are quite low, indicating that they are potentially nitrogen-limited. The absolute values of the biologically available forms of nitrogen are also significantly lower than the river dominated estuaries.

Table 16: Lagoons: Shallow and Well Mixed Estuarine Averages

Estuarine - Shallow	Spring	Summer	Fall	Winter
Temperature (^{o}C)	16.8	22.4	11.6	5.1
Salinity (PPT)	25.7	28.7	28.2	23.9
Secchi Depth (feet)	3.3	2.9	3.5	3.9
Suspended Solids (mg/L)	41.3	44.1		
Dissolved Oxygen (% Saturation)	72.6	72.5	67.3	66.2
Ammonia (µg N/L)	19.3	69.0	37.2	27.7
Nitrate + Nitrite (µg N/L)	11.5	18.0	36.2	43.4
Orthophosphate (µg P/L)	19.4	39.1	21.7	12.8
Organic Nitrogen	350.2	465.4	336.5	307.9
Inorganic N:P ratio	2.0	2.4	4.4	7.9
Fecal Coliform MPN (geometric mean)	6.0	11.0	10.5	8.7

Rivers

Compared to the other categories of waterbodies evaluated, the salinity at the river sites was significantly lower. Dissolved oxygen (% saturation) approximated that found in shallow, well-mixed estuaries. The N:P ratio shifted according to the season, indicating the potential for the river systems to vacillate between nitrogen limited conditions and phosphorus limited conditions. The concentration of biologically available nitrogen compounds tended to be relatively high, reflecting the input of nutrients into the estuarine system from upgradient sources.

Table 17: River Averages

River	Spring	Summer	Fall	Winter
Temperature (^oC)	15.8	24.8	13.8	3.6
Salinity (PPT)	5.8	9.2	13.0	6.8
Secchi Depth (feet)	2.3	2.1	2.4	3.0
Suspended Solids (mg/L)		29.0		
Dissolved Oxygen (% Saturation)	76.4	69.9	76.5	87.8
Ammonia (µg N/L)	48.2	66.2	69.6	63.8
Nitrate + Nitrite (µg N/L)	131.9	76.4	130.0	358.2
Orthophosphate (µg P/L)	21.3	26.0	18.7	14.6
Organic Nitrogen	561.6	497.2	455.3	569.6
Inorganic N:P ratio	14.0	8.2	16.9	34.6
Fecal Coliform MPN (geometric mean)	40.6	102.7	91.8	4.9

Tidal Tributaries

The tidal tributaries typically drain a relatively small upland area that may include wetlands. The salinity in these areas tends to be very low. The water is frequently turbid, reflecting the input of material from the upland areas into the estuary system. The N:P ratios tend to be very high, indicating that the areas are probably phosphorus limited. In general, the biologically available nitrogen, particularly nitrate-N tends to be very high, while the levels of phosphorus tend to be relatively low.

Table 18: Tidal Tributary Averages

Tidal Tributary	Spring	Summer	Fall	Winter
Temperature (^{o}C)	9.7			
Salinity (PPT)	0.5			1.0
Secchi Depth (feet)	1.6			
Suspended Solids (mg/L)				
Dissolved Oxygen (% Saturation)	78.6			
Ammonia (g N/L)	24.6			364.0
Nitrate + Nitrite (g N/L)	295.0			1009.2
Orthophosphate (g P/L)	4.3			4.9
Organic Nitrogen	639.9			1539.3
Inorganic N:P ratio	63.2			455.9
Fecal Coliform MPN (geometric mean)	16.6			8.1

Inlets

Samples from inlet areas are obtained where the estuary and the open ocean meet. Typically, the salinity profile is similar to that of the ocean (30-32 PPT). Dissolved oxygen tends to be close to saturation. Absolute values of biologically available nutrients tend to be relatively low, with a low N:P ratio indicative of nitrogen limited waters.

Table 19: Inlet Averages

Inlet	**Spring**	**Summer**	**Fall**	**Winter**
Temperature (^{o}C)	15.3	19.1	12.4	5.5
Salinity (PPT)	31.2	31.5	32.0	30.7
Secchi Depth (feet)	4.3	3.6	3.3	6.2
Suspended Solids (mg/L)	39.2	46.0		
Dissolved Oxygen (% Saturation)	90.4	81.0	77.5	65.3
Ammonia (µg N/L)	13.8	52.9	37.1	17.6
Nitrate + Nitrite (µg N/L)	29.9	15.4	41.5	51.1
Orthophosphate (µg P/L)	18.1	31.5	22.2	12.6
Organic Nitrogen	272.3	309.6	258.2	166.1
Inorganic N:P ratio	2.0	2.1	4.3	6.3
Fecal Coliform MPN (geometric mean)	4.0	9.0	5.6	9.1

Ocean

Since ocean samples were not obtained for every season, it is difficult to compare these values to those found in other types of waterbodies. However, it should be noted that the dissolved oxygen tended to be high, reflecting super-saturated conditions.

Table 20: Ocean Averages

Ocean	Spring	Summer	Fall	Winter
Temperature (^oC)	22.2			
Salinity (PPT)	31.8			
Suspended Solids (mg/L)	38.8			
Dissolved Oxygen (% Saturation)	115.2			
Nitrate + Nitrite (µg N/L)	63.9			
Orthophosphate (µg P/L)	11.0			
Organic Nitrogen	243.2			

Ocean (near sanitary discharges)

Samples obtained in the vicinity of sanitary discharges are evaluated separately from others obtained in the ocean because of the potential for nutrient impacts resulting from the discharge of wastewater. Since samples were not obtained for every season, it is difficult to compare these values to those found in other types of waterbodies. However, it should be noted that the dissolved oxygen tended to be high, reflecting super-saturated conditions.

Table 21: Ocean (near sanitary discharge) Averages

Ocean Near Outfall	Spring	Summer	Fall	Winter
Temperature (^oC)	22.7			
Salinity (PPT)	31.1			
Suspended Solids (mg/L)	41.7			
Dissolved Oxygen (% Saturation)	126.5			
Nitrate + Nitrite (µg N/L)	61.8			
Orthophosphate (µg P/L)	10.7			
Organic Nitrogen	278.6			

Phytoplankton Monitoring

Levels of phytoplankton are measured at regular intervals throughout the summer at several locations throughout the coastal waters. Dominant species are identified and enumerated. Reports are prepared after each sampling episode and an annual summary report is published at the conclusion of the year. For the period of record discussed in this report, the speciation and enumeration were completed by the Bureau of Freshwater and Biological Monitoring.

The monitoring is required in accordance with the National Shellfish Sanitation Program. It is important to identify planktonic species that have the potential to adversely affect the suitability of shellfish for human consumption.

Algal blooms were reported each year for the period 1993 – 1997. The areas most severely impacted include: Raritan / Sandy Hook Bay, Barnegat Bay, and sporadic offshore areas. Death and decay of algal populations resulted in hypoxic conditions in 1995 and 1997. Fish kills were associated with the low dissolved oxygen.

Trends in Water Quality (1989 – 1997)

Data have been regularly collected through the estuarine monitoring project for eight years. This array of long tern data provides an opportunity to begin to assess the trends in water quality in the coastal areas of New Jersey for parameters that impact primary productivity.

Mean values for Secchi depth, total nitrogen, salinity, orthophosphate, nitrate/nitrite, ammonia, and geometric mean values for fecal coliform were evaluated and compared across the three time periods: 1989 – 1990, 1990 – 1993, and 1993 – 1997. Minimum values of dissolved oxygen were compared for the same time periods.

Secchi Depth

Secchi depths (in feet) are a measure of relative turbidity. They were obtained at each station. As shown in Figures 2 - 4, there were no major differences among the three report periods. The area from Little Egg Harbor to Reeds Bay had Secchi depths slightly less during 1989-1990 than in subsequent years. Increases in water clarity can be an indication of improving water quality.

The pattern of water clarity in the Delaware Bay is typical of that to be expected in a large Bay: The water is more turbid in upgradient areas and less turbid in areas closer to the ocean.

Table 22: Comparison of Secchi Depths

Area	Secchi Depth (feet)	
	Minimum	Maximum
Atlantic Ocean	5.1	11.0
Delaware Bay - overall	2.1	11.0
Delaware Bay – western section	2.1	3.0
Delaware Bay – central section	3.1	4.0
Delaware Bay – eastern section	5.1	11.0
River Estuarine	1.1	2.0

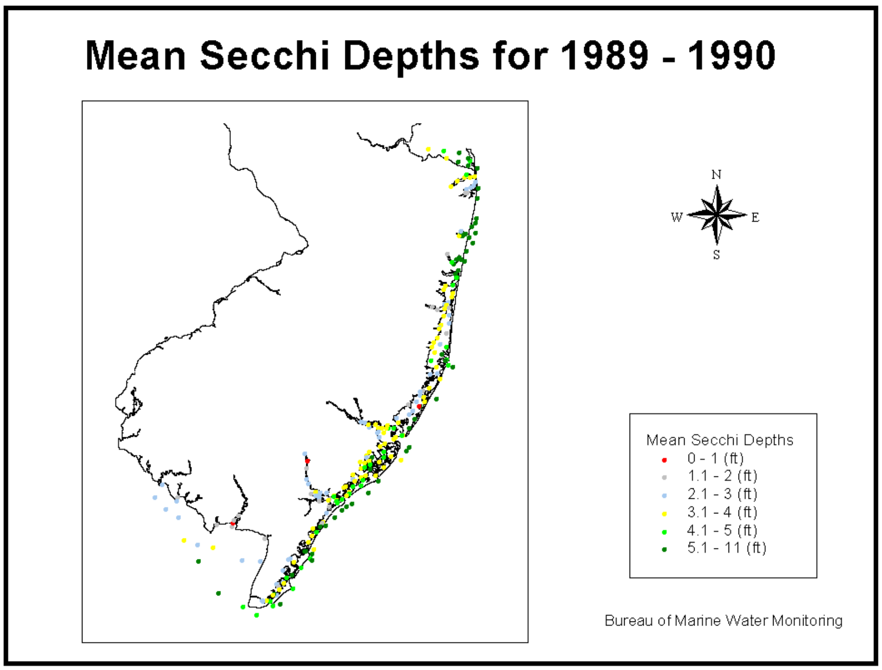


Figure 17: Secchi Depths (1989-1990)

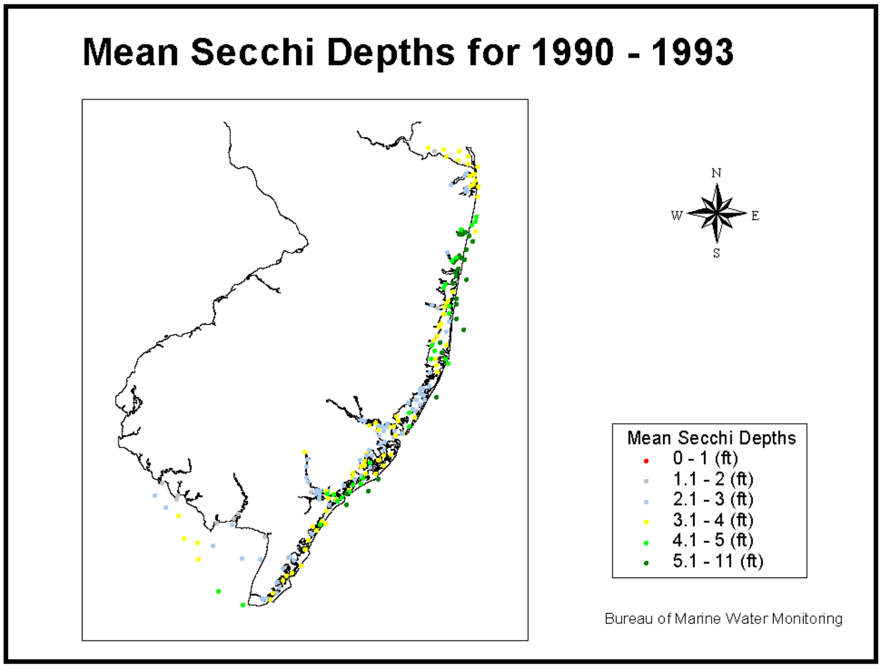
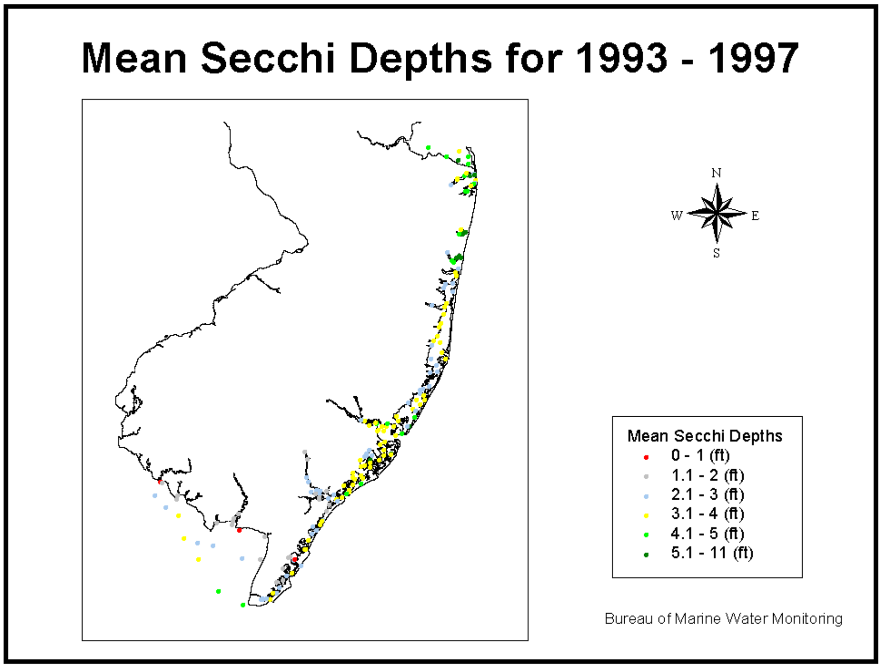


Figure 18: Secchi Depths (1990-1993)

Figure 19: Secchi Depths (1993-1997)



Salinity

Salinity was classified using the NOAA classification standard in which the waters were considered to be a 'mixing area' classification when the salinity value fell within a 0 - 25 PPT range or a 'seawater' classification when the value fell within 25.1 - 34 PPT range. As shown in Figures 5 – 7, when the salinity values were mapped there were no major differences except in one area. This area was Sandy Hook Bay / Raritan Bay. For the 1989 - 1990 time period Sandy Hook bay was classified as seawater and Raritan Bay was classified as a mixing area. During 1990 - 1993 both bays were classified as mixing areas. During the 1993 – 1997 time period both bays were classified as predominately seawater. This pattern is not unusual in areas where the salinity is close to the arbitrary value indicating a different classification.

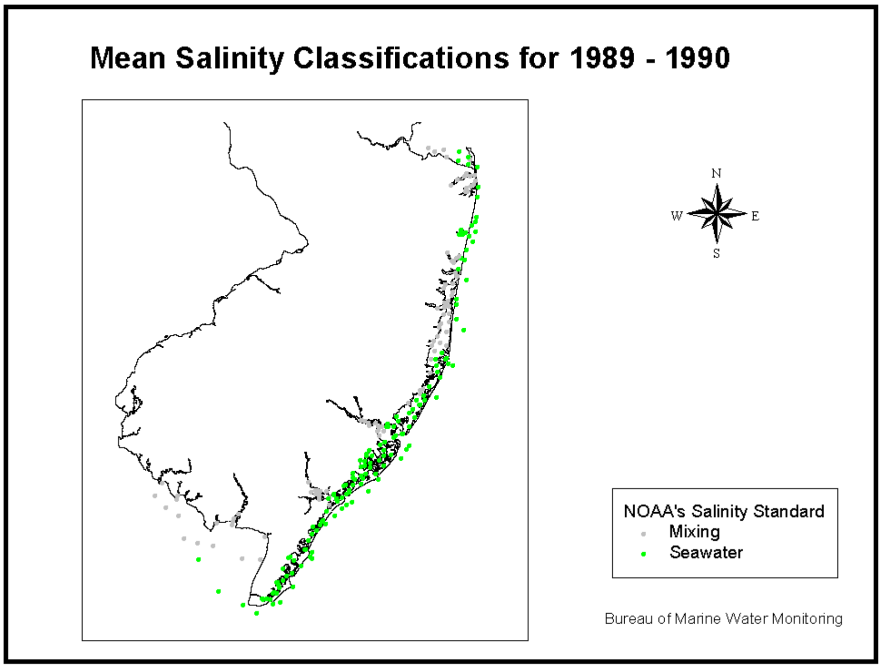


Figure 20: Salinity (1989-1990)

Figure 21: Salinity (1990-1993)

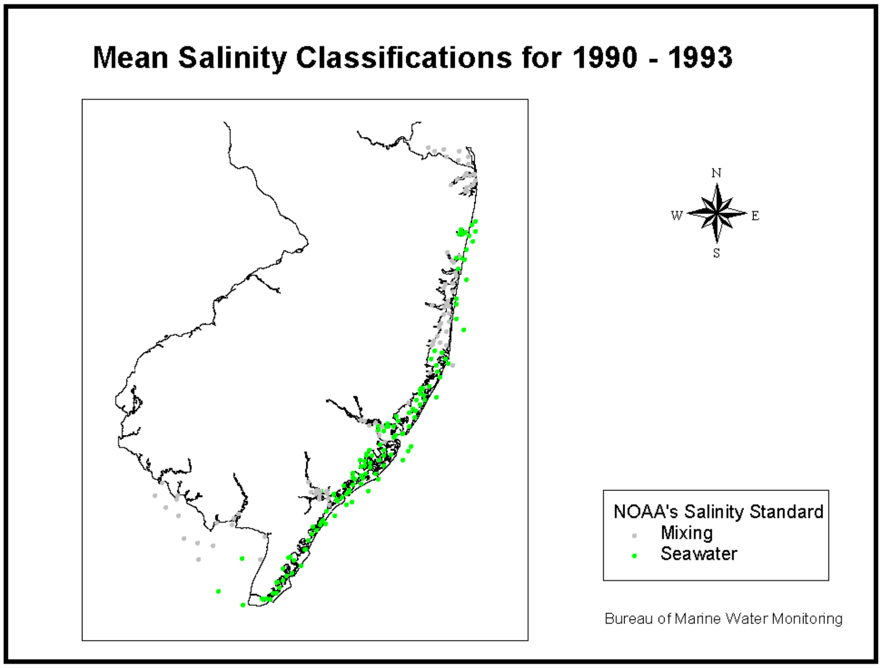
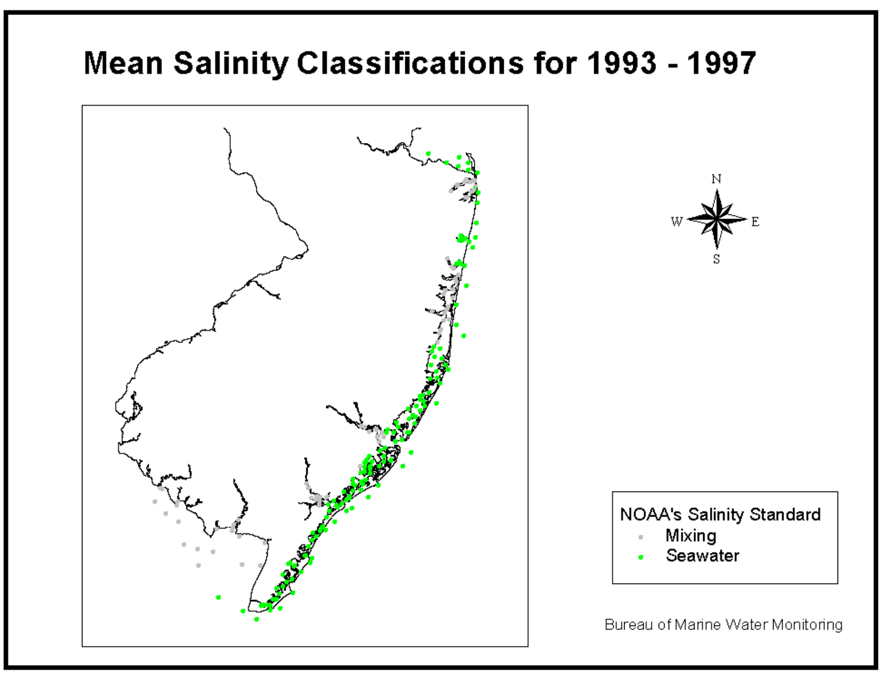


Figure 22: Salinity (1993-1997)



Dissolved Oxygen

Dissolved Oxygen showed the most change from 1989 to 1997. Maps depicting the data are shown in Figures 24 - 26.

Dissolved Oxygen was classified using the State Surface Water Quality Standard. Acceptable water quality in the ocean is a minimum concentration of 5.0 mg/L. Acceptable water quality in estuaries is a minimum concentration of 4.0 mg/L.

For the report period of 1989 – 1990 all the sampling stations met the acceptable standard with the exception of 12 stations. These unacceptable values were found primarily in the lower Wildwood and Cape May area and at the mouth of a few Delaware Bay tributaries.

During the 1990 – 1993 report period the state again met the acceptable standard with the exception of eight stations. However, the stations were not in the Wildwood/Cape May area but three stations were in the Great Egg Harbor River and two are in the Navesink River. The remaining stations are sporadically located through the state.

During the 1993 – 1997 report period approximately half of the stations were unacceptable with the majority of the stations concentrated from Barnegat south to Great Egg Harbor. Since the occurrence of these low dissolved oxygen concentrations coincided with phytoplankton blooms, it is likely that the bloom and subsequent die-off of the plankton was a significant factor in precipitating the low oxygen levels.

Table 23: Minimum Dissolved Oxygen in Selected Areas

Waterbody	Dissolved Oxygen Level (mg/L)		
	1989-1990	1990-1993	1993-1997
Raritan Bay	> 4.0	> 4.0	< 4.0
Sandy Hook	> 4.0	> 4.0	< 4.0
Navesink River	> 4.0	< 4.0	< 4.0
Barnegat Bay	> 4.0	> 4.0	< 4.0
Great Bay / Mullica River	> 4.0	> 4.0	< 4.0
Great Egg Harbor	> 4.0	< 4.0	< 4.0

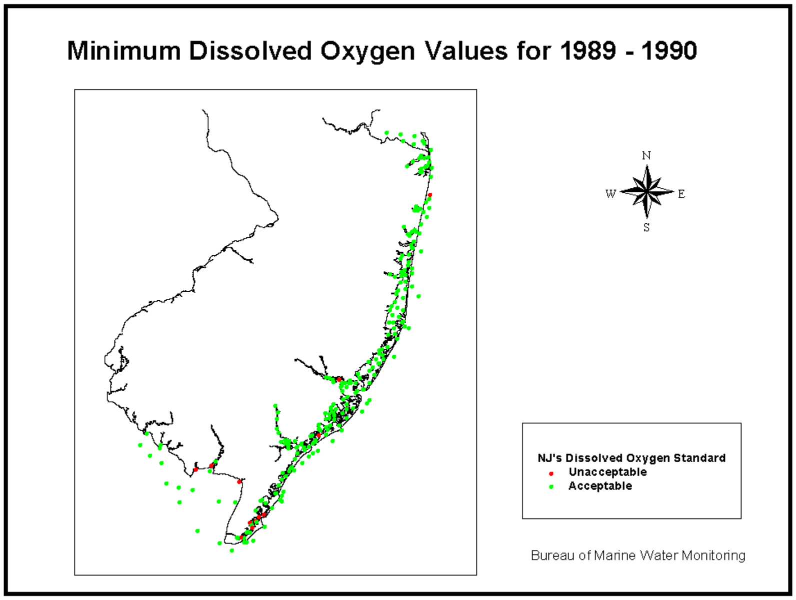


Figure 23: Dissolved Oxygen (1989 - 1990)

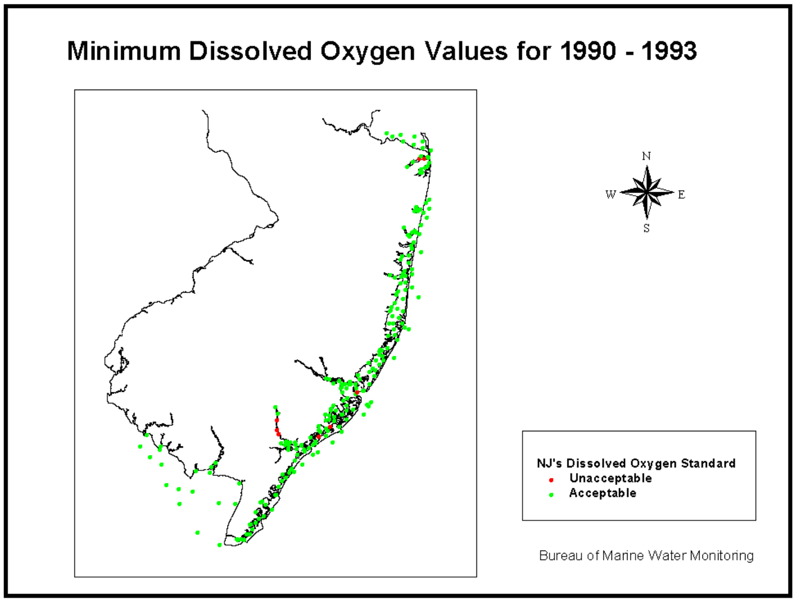


Figure 24: Dissolved Oxygen (1990 - 1993)

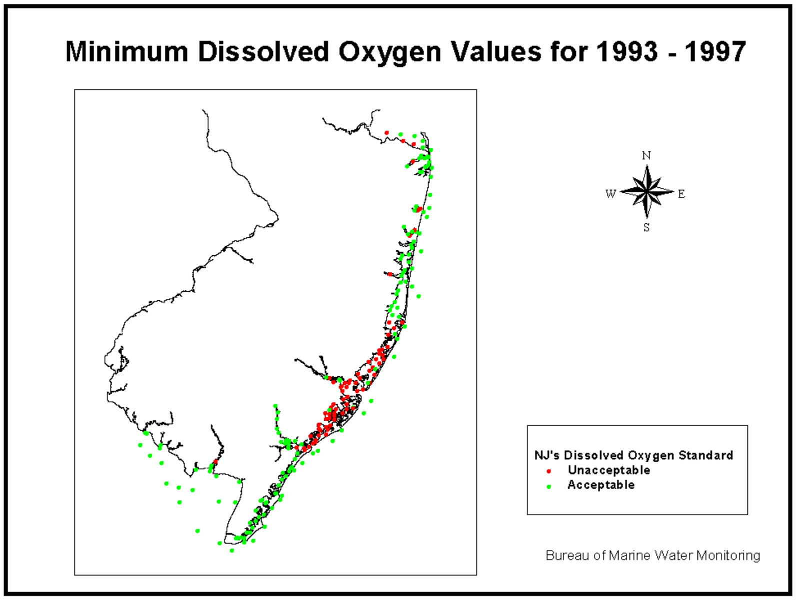


Figure 25: Dissolved Oxygen (1993 - 1997)

Analysis of dissolved oxygen data from the shallow estuaries between Great Bay and Great Egg Harbor River reveal a downward trend in dissolved oxygen concentration. Trend data for two stations (Lakes Bay and Absecon Bay) are shown below. These stations are typical of sampling stations in this area.

During the period from 1993 through 1996, dissolved oxygen concentrations have dropped sharply during the spring and summer, compared to data collected prior to 1993. Based on these data points, dissolved oxygen is low enough during parts of the warmer weather months to cause biological stress for aquatic organisms.

While there is not sufficient data to identify causes of this trend, it is likely that the lowered dissolved oxygen levels are due to one or a combination of the following factors:

- Input of oxygen depleted waters from the tidal wetlands adjoining the Bays
- Increased algal blooms stimulated by increased levels of nutrients
- Increased loading of oxygen depleting substances from nonpoint sources of pollutants.

Since the pattern is distinctly seasonal, with much lower levels of oxygen during warmer months, it is most likely that the low dissolved oxygen levels are related to increased levels of nutrients entering the waterbodies and the consequent increase in algal population. The associated biological activity due to both respiration and senescence would act to deplete oxygen levels.

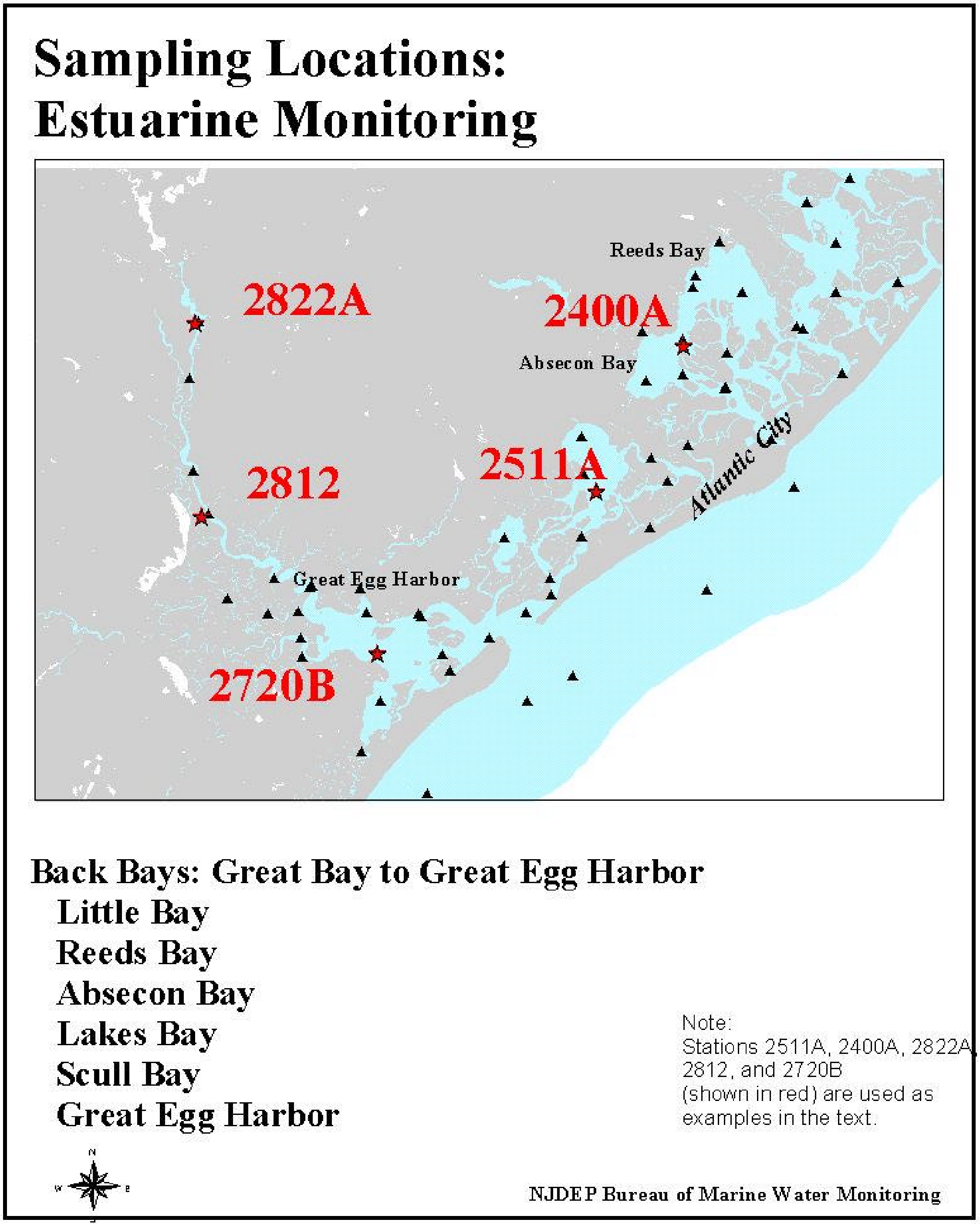


Figure 26: Location of Stations for Trend Analysis in Back Bays

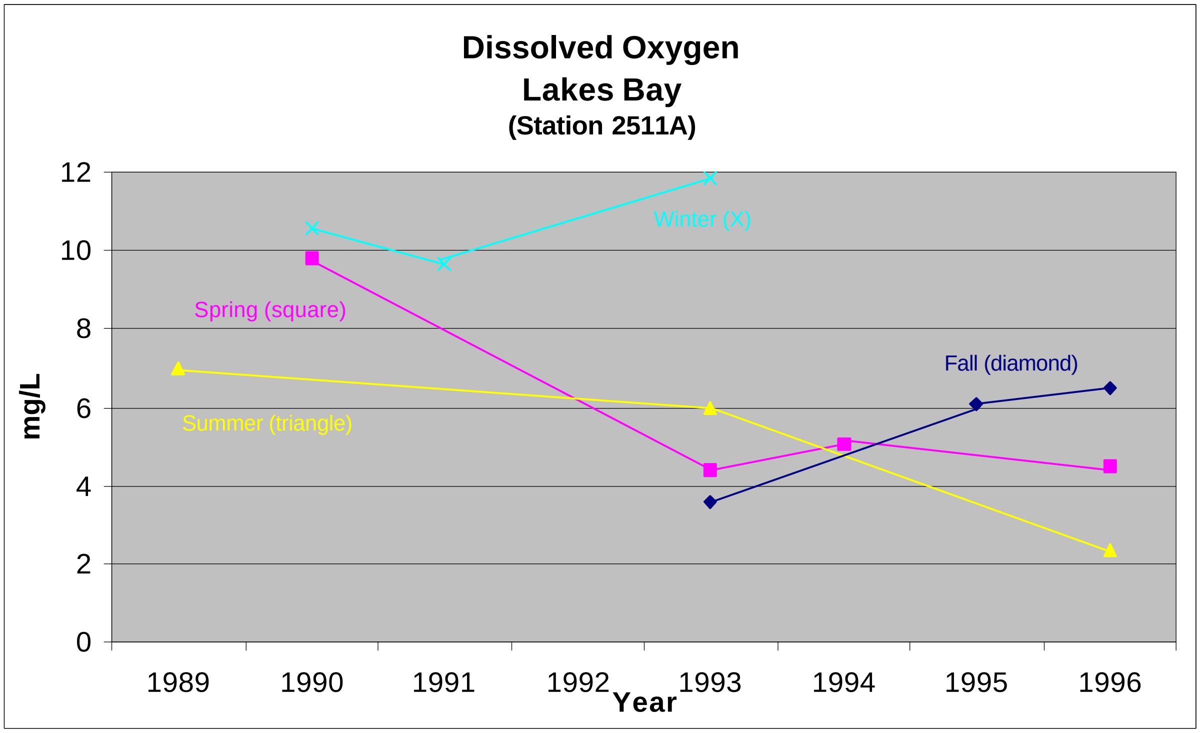


Figure 27: Dissolved Oxygen Trend -- Lakes Bay

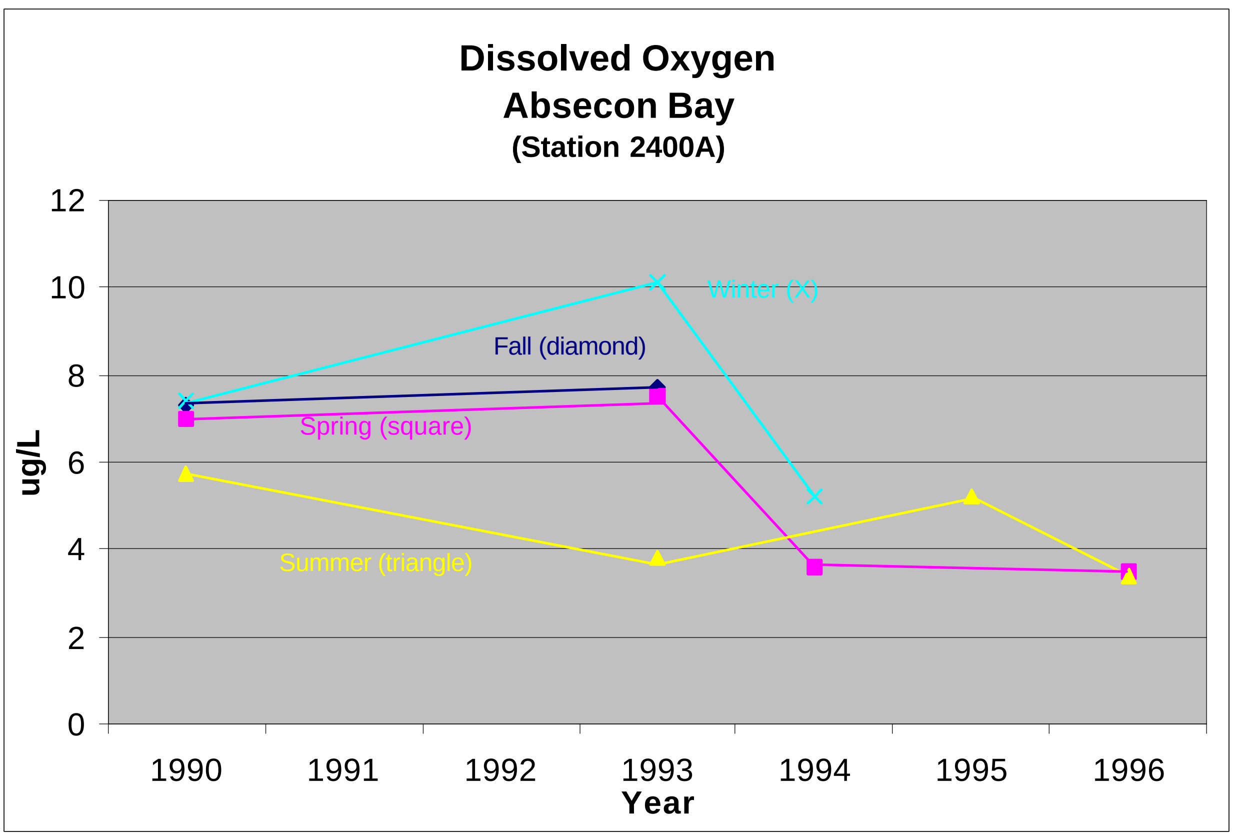


Figure 28: Dissolved Oxygen Trend -- Absecon Bay

Ammonia

Ammonia values were also classified in six increments of 25, 50, 100, 200, & 300 µg N/L. Maps depicting the data are shown in Figures 13 - 15. Ammonia values ranged from 0 – 700 µg N/L. This is in sharp contrast to the measured values for nitrate / nitrite where most of the stations were in the 0 – 200 µg N/L range.

The areas of greatest change were in the Raritan /Sandy Hook Bay, and the area between Great Egg Harbor Bay and Great Bay. In general ammonia-N levels tended to be higher in the summer and fall.

Table 24 : Ammonia-N Trends in Selected Areas

Waterbody	Ammonia Level (µg N/L)		
	1989-1990	1990-1993	1993-1997
Great Egg Harbor River	100 - 200	50 - 100	50 - 100
Absecon Bay	0 - 50	50 - 100	50 - 100
Mullica River	50 - 100	25 - 50	25 - 50
Great Bay	0 - 100	0 - 100	25 - 50
Sandy Hook Bay	< 50	50 - 100	50 - 100
Raritan Bay	100 - 200	200 - 400	100 - 200

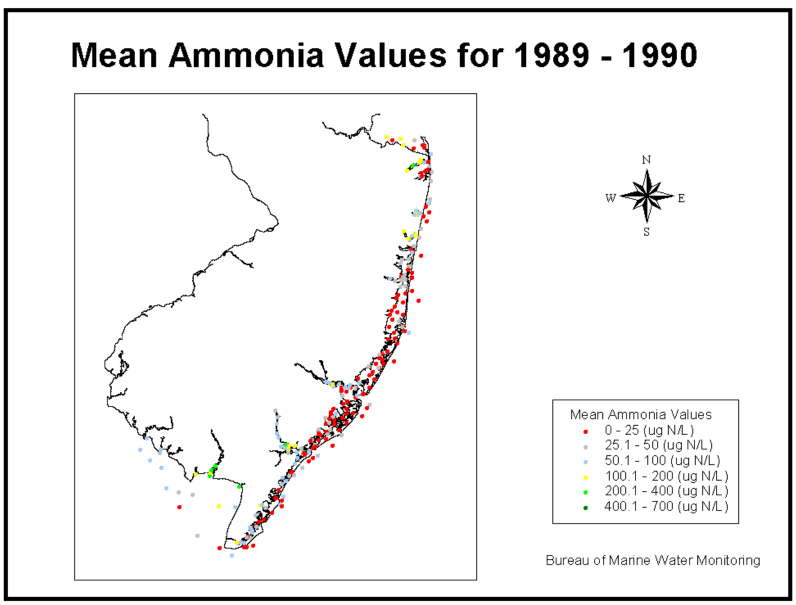


Figure 29 : Ammonia-N (1989-1990)

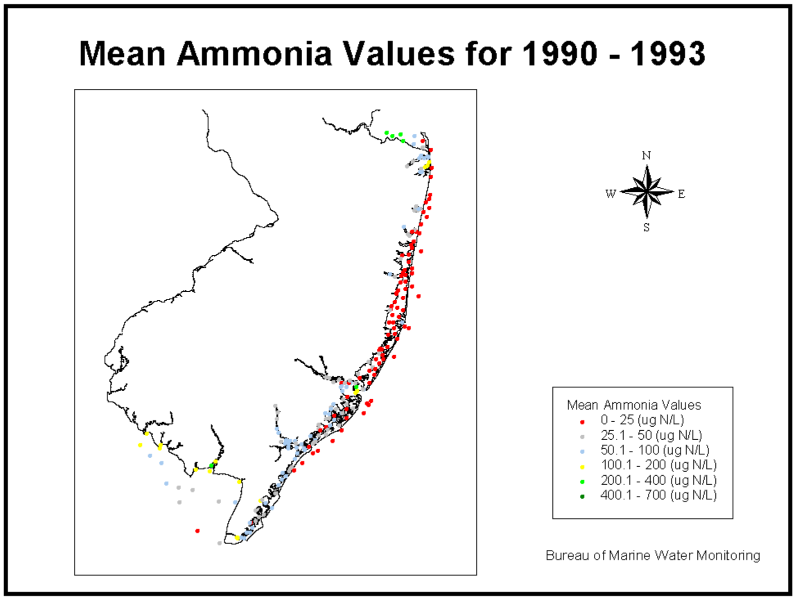


Figure 30: Ammonia-N (1990-1993)

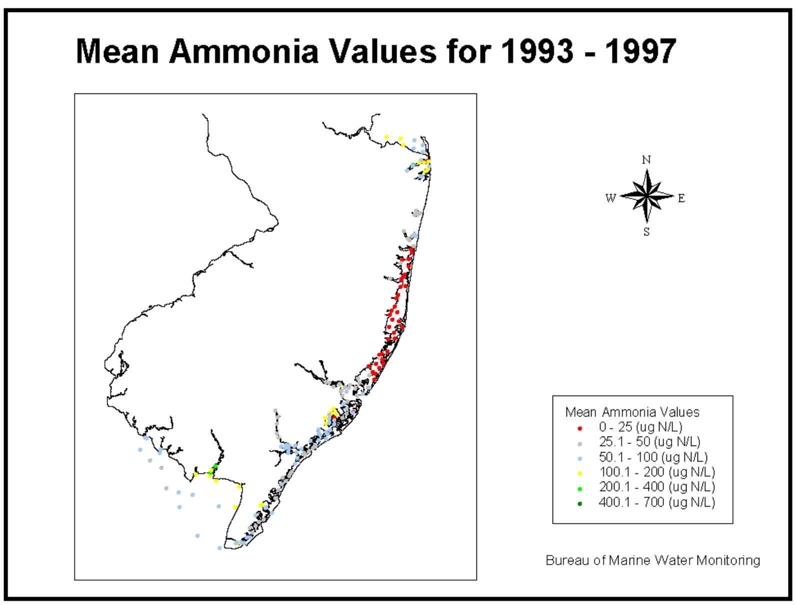


Figure 31: Ammonia-N (1993-1997)

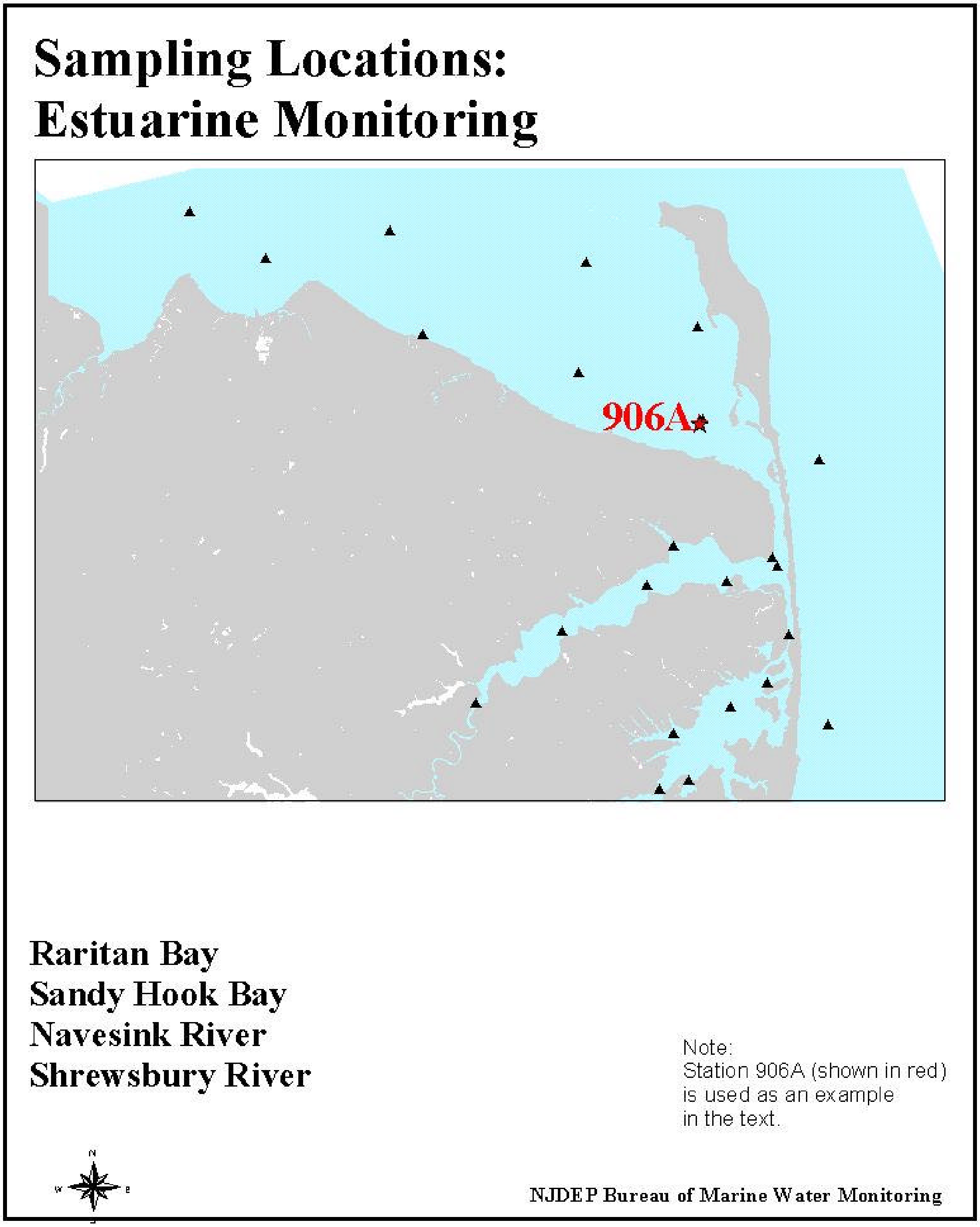


Figure 32: Location of Stations for Trend Analysis in Raritan / Sandy Hook Bay

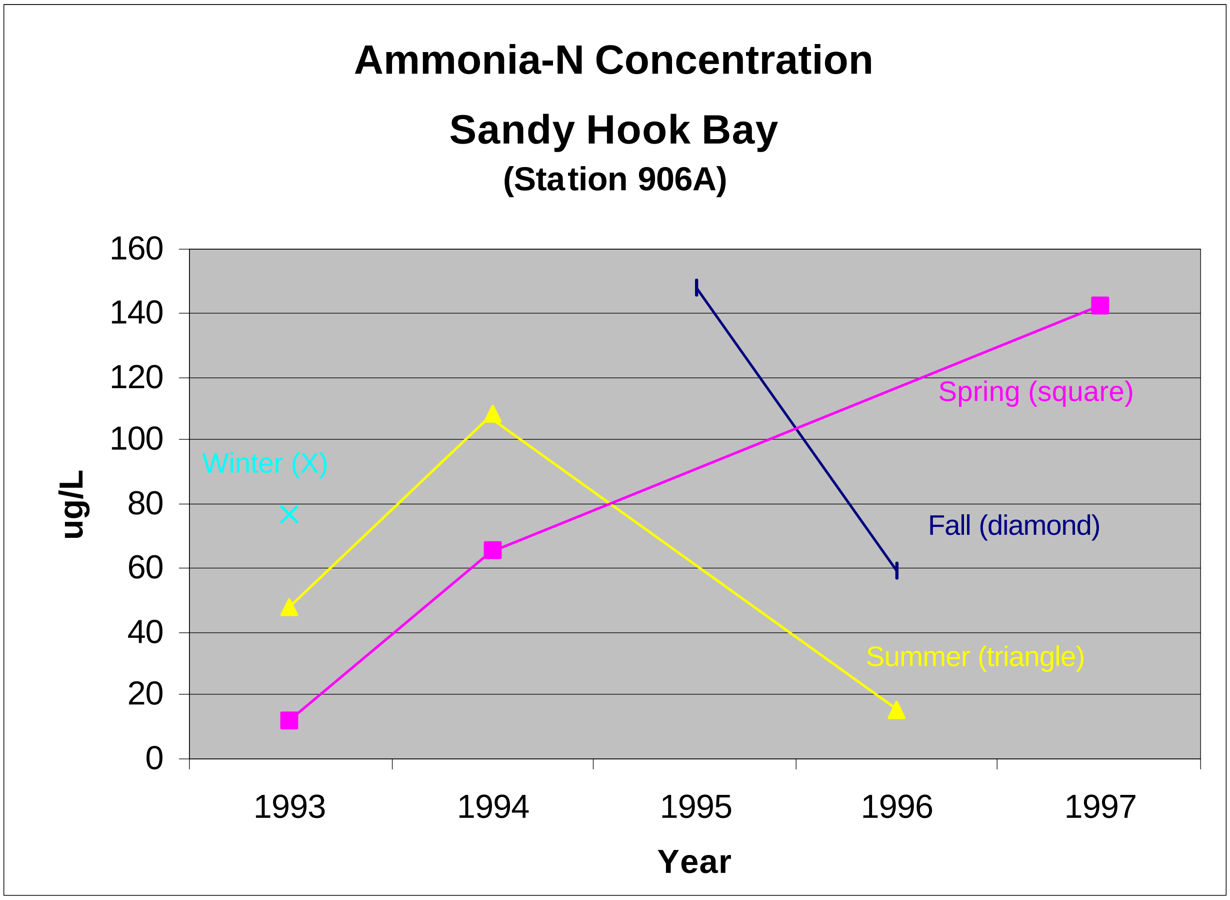


Figure 33: Ammonia-N Trend: Sandy Hook Bay

Although the overall trend in the Sandy Hook Bay / Raritan Bay area seems to be for higher concentrations of ammonia-N, when the data are examined with a seasonal component, the pattern is less clear. As can be seen in the Figure above, fall and summer concentrations of ammonia-N appear to be declining. However, concentrations in the spring appear to be increasing. Other sampling stations show a similar pattern, so that it is not clear that the overall water quality of the area is improving or declining.

Conversely, in Absecon Bay, concentrations of ammonia-N appear to be significantly increasing during the spring and summer. These increases correlate with concomitant decreases in dissolved oxygen in Absecon Bay during the same period.

This pattern (significant increases of ammonia-N concentrations during the warm weather months) is similar throughout the shallow estuaries between Great Bay and Great Egg Harbor River. (See the brief discussion in the section on dissolved oxygen.) It is this trend toward increases in nitrogen inputs, combined with oxygen depletion during the same time period that suggests that the primary cause of the oxygen depletion may be dependent on the nutrient increases.

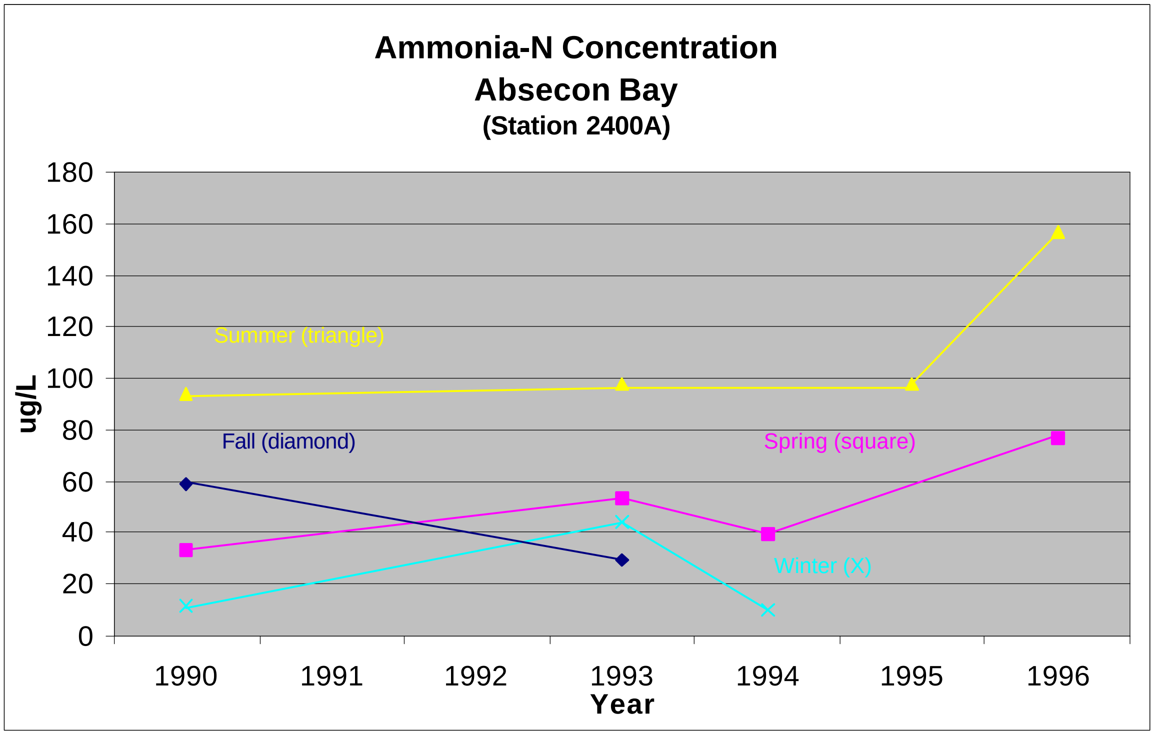


Figure 34: Ammonia-N Trend: Absecon Bay Area

Nitrate / Nitrite

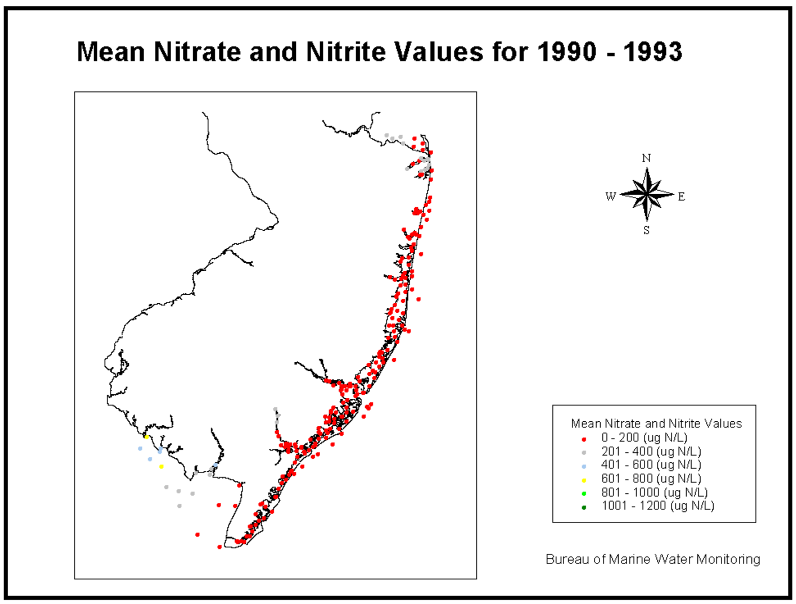
Nitrate / nitrite was classified in six categories ranging from 0 – 1200 µg N/L. Each category was of an increment of 200 µg N/L. Maps depicting the data are shown in Figures 8 - 10. Most levels were below 200 µg N/L throughout the time period of record. The general trend for areas with higher levels of nitrate/nitrite at the outset of the study was downward.

The values given below are averages of all data collected at that location. Thus, it does not reflect seasonal patterns, but general trends. In general, the highest levels were measured during the cold weather months, while significantly lower levels were measured during the summer.

Table 25: Nitrate/Nitrite Trends in Selected Areas

Waterbody	Nitrate/Nitrite Level (µg N/L)		
	1989-1990	1990-1993	1993-1997
Great Egg Harbor River	401 - 600	201 - 400	< 200
Maurice River	401 - 600	401 - 600	201 - 400
Nantuxent Cove	801 - 1000	401 - 600	401 – 600
Delaware Bay (between Maurice River and Nantuxent Cove)	201 - 400	601 - 800	401 - 600

Figure 35: Nitrate / Nitrite (1990-1993)



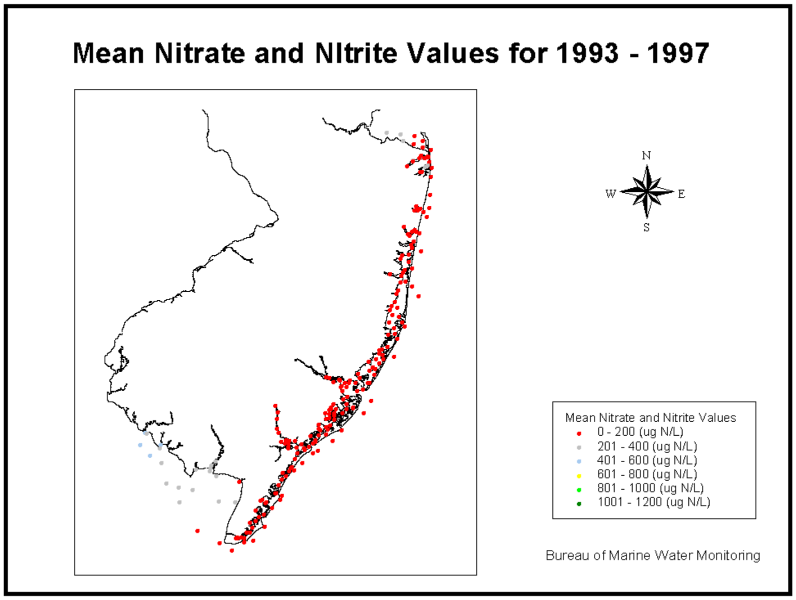


Figure 36: Nitrate / Nitrite (1993-1997)

However, when the seasonal distribution of nitrate-N is considered, the trend becomes more complex. As can be seen in the three plots for the Great Egg Harbor River (below), the general pattern for elevated nitrate-N during the winter (compared to spring, summer, and fall) is accurate at all three sampling stations. However, the concentration in the upper river is about twice the concentration midway down the river and about 6-8 times the concentration in the Bay, particularly during the winter. In other seasons, the proportion is less, probably due in part to the uptake of nitrogen by algae through primary production.

This pattern indicates the potential for a significant proportion of the nitrogen load in the River and Bay to be due to upstream inputs, presumably nonpoint source inputs. (There are no significant point sources located in this area.)

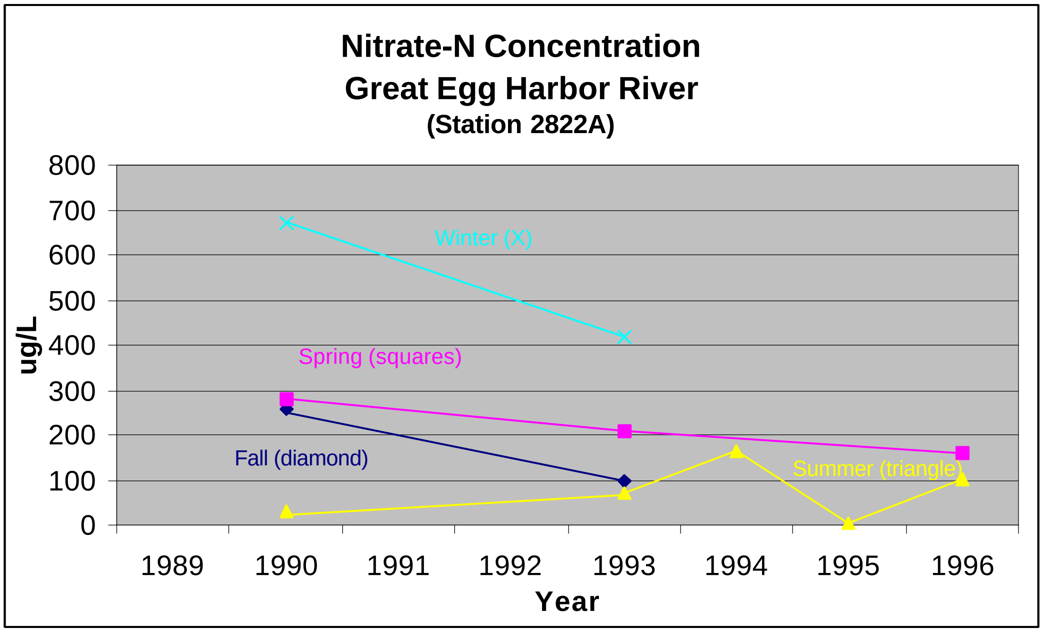


Figure 37: Nitrate-N Trend. Great Egg Harbor (upper river)

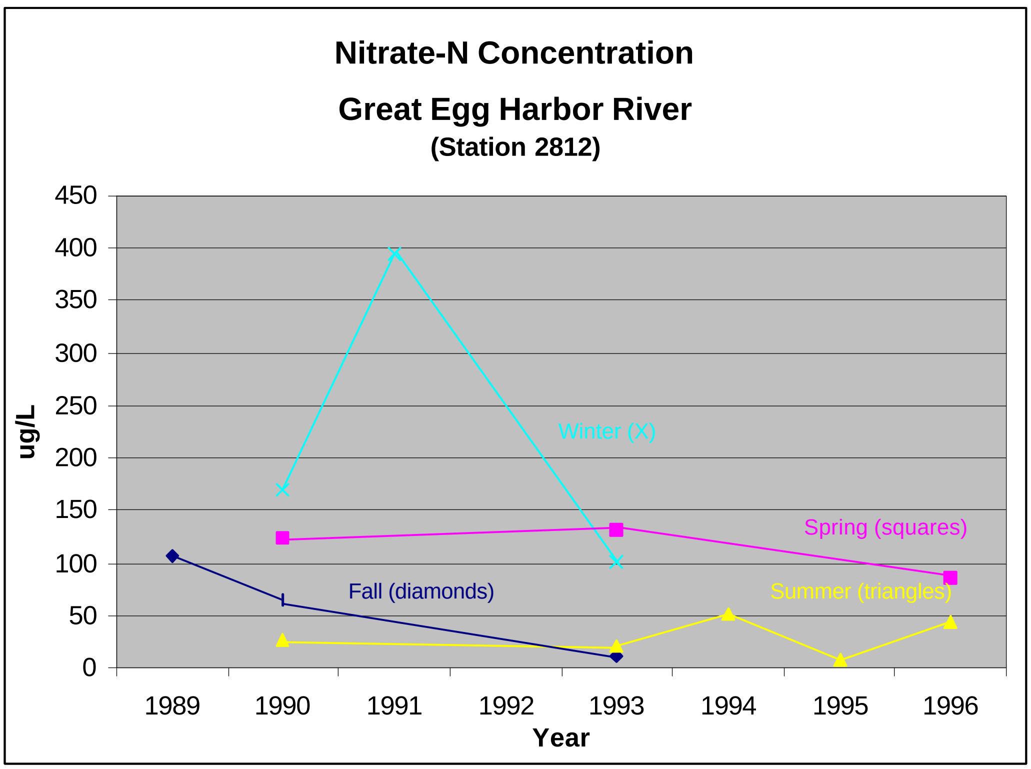


Figure 38: Nitrate-N Trend. Great Egg Harbor (mid-river)

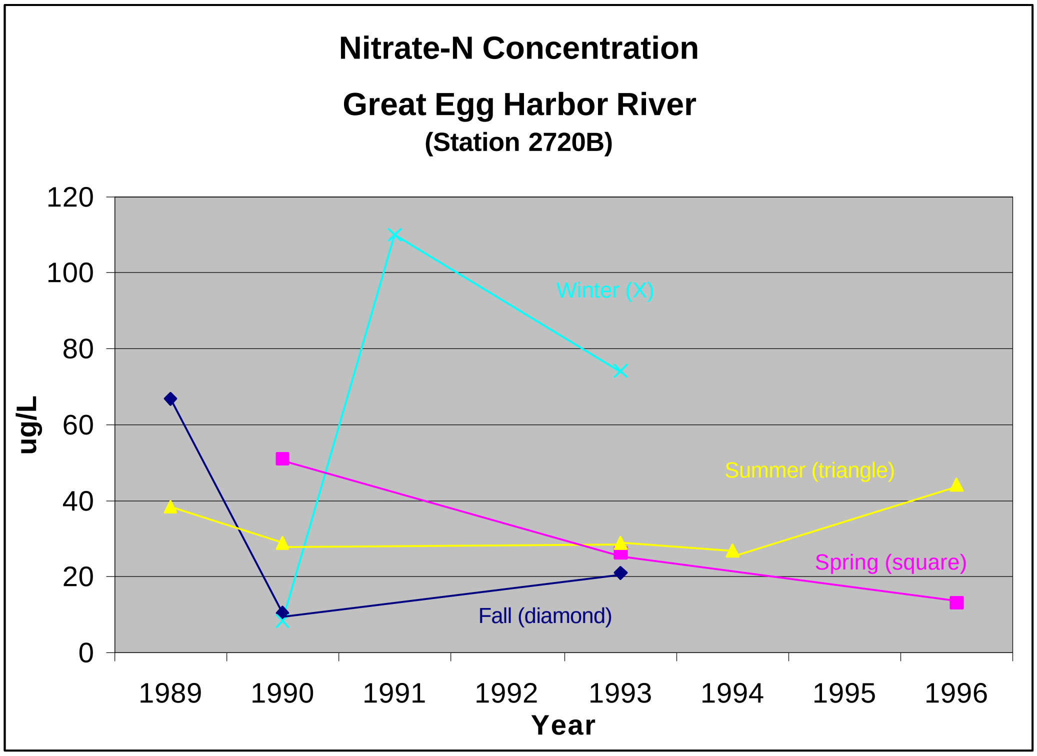


Figure 39: Nitrate / Nitrite Trend: Great Egg Harbor (mid Bay)

Similarly, while the overall trend of nitrate-N in the near-shore areas of the Delaware Bay indicate modest decreases, when the seasonal trends are considered, the pattern becomes more complex. While there have been decreases in concentration during the warmer weather in Maurice River Cove, winter samples were not obtained in 1994-1996, thus skewing the overall trend downward.

Likewise, winter samples were not obtained in Nantuxent Cove in 1994-1996. However, the seasonal trend is slightly different in that there have been slight decreases in summer, but increases in both spring and fall.

Unlike the shallow estuaries between Great Bay and Great Egg Harbor River, increases in nutrient levels in the Delaware Bay do not seem to result in oxygen depletion. However, Delaware Bay is one of the areas where algal blooms frequently occur during the warm weather. (For detailed information on algal blooms in New Jersey coastal waters, consult the annual reports summarizing the regular biweekly algal monitoring.)

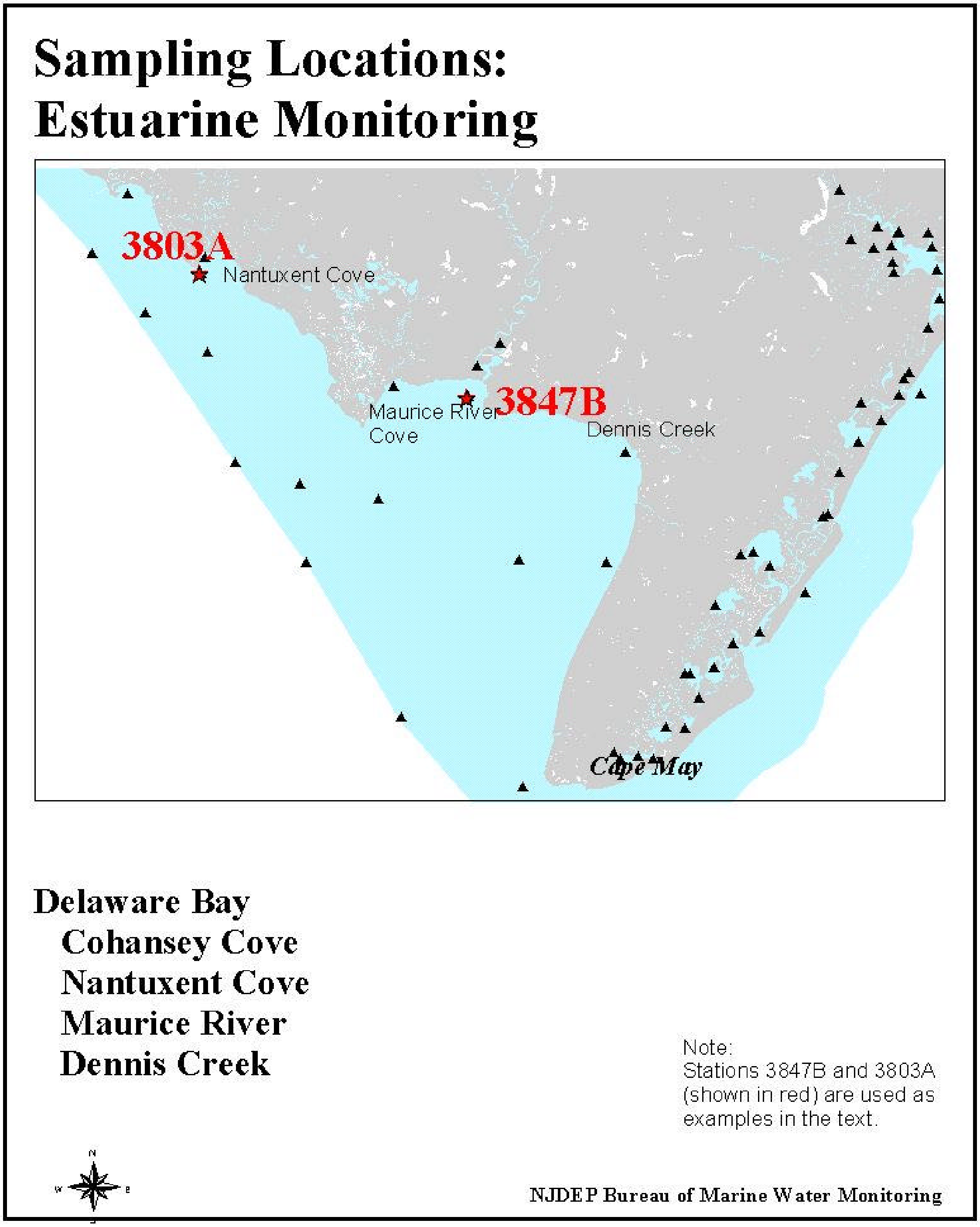


Figure 40: Location of Stations for Trend Analysis in Delaware River

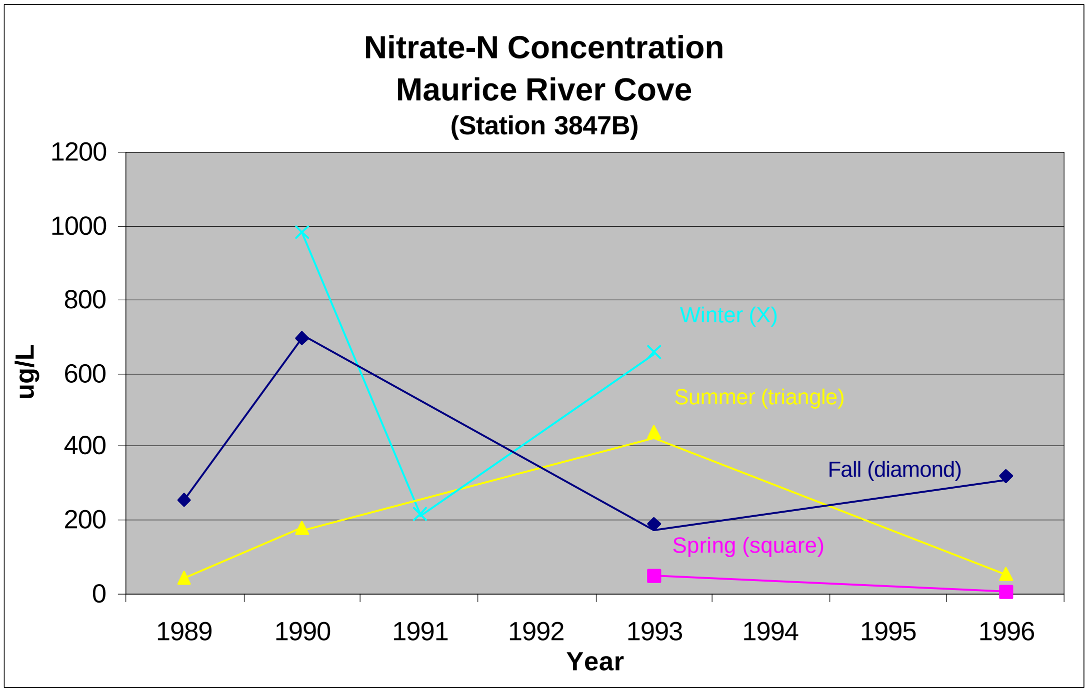


Figure 41: Nitrate-N Trend: Delaware Bay

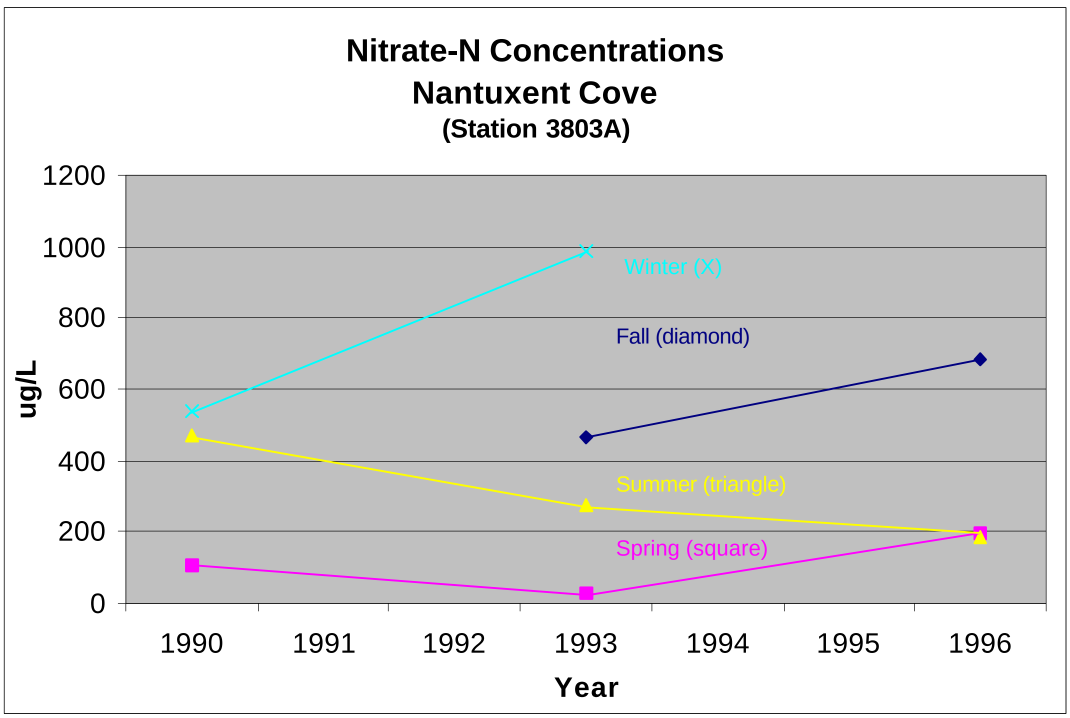


Figure 42: Nitrate / Nitrite Trend: Delaware Bay

Total Nitrogen

Total nitrogen was classified in six increments of 200 µg N/L ranging from 0 – 1400 µg N/L. Maps depicting the data the data are shown in Figures 18 - 20. Unlike the biologically available forms of nitrogen, total nitrogen (with its strong component of compounds tied up in organic matter) does not exhibit the strong seasonal pattern shown by ammonia-N and nitrate/nitrite-N. Although there are some indications of lower concentrations of total nitrogen, much of this trend is due to decreases in the biologically available components.

Table 26: Total Nitrogen Trends in Selected Areas

Waterbody	Total Nitrogen Level (µg N/L)		
	1989-1990	**1990-1993**	**1993-1997**
Sandy Hook / Raritan Bay	601 - 1000	601 - 800	601 - 800
Navesink River	601 - 1000	601 - 800	601 - 800
Shrewsbury River	601 - 1000	601 - 800	601 - 800
Barnegat Bay	401 - 600	401 - 600	601 - 800
Great Egg Harbor River	601 - 1000	401 - 800	401 - 600

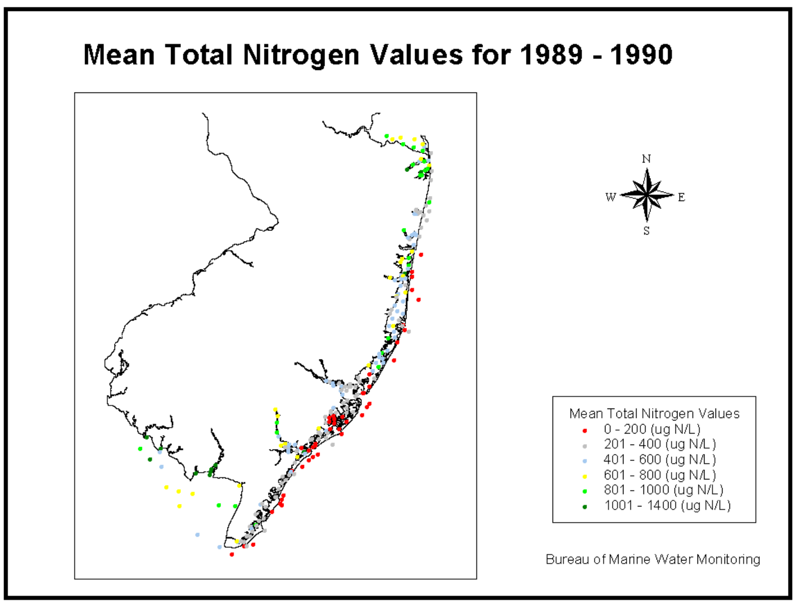


Figure 43: Total Nitrogen (1989-1990)

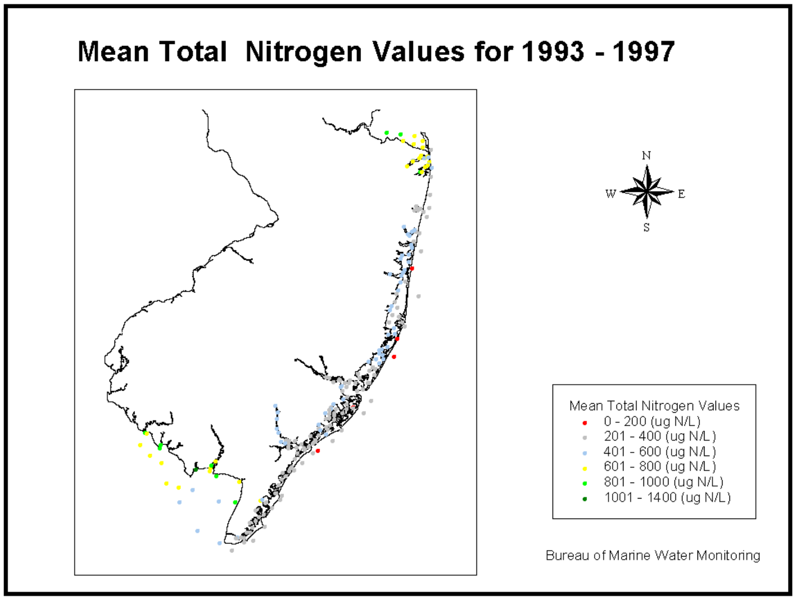


Figure 44: Total Nitrogen (1993-1997)

Orthophosphate

Orthophosphate values were classified in five increments ranging from 0 to 350 µg P/L. Maps depicting the data are shown in Figures 21 - 23. The orthophosphate values for the three time periods were very similar. The majority of the stations were in the 0 – 30 µg P/L range. Significant increases were measured at some sites in Raritan / Sandy Hook Bay and Shrewsbury / Navesink River during the three periods. These increases may be due to increased loading from stormwater runoff. Orthophosphate levels tend to be highest in the summer.

Table 27 : Orthophosphate Trends in Selected Areas

Waterbody	Orthophosphate Level (µg P/L)		
	1989-1990	1990-1993	1993-1997
Raritan Bay	0 - 30	61 - 90	91 - 120
Sandy Hook	31 - 60	31 - 60	91 - 120
Navesink River	31 - 60	31 - 60	121 - 350
Shrewsbury River	61 - 90	31 - 60	121 - 350

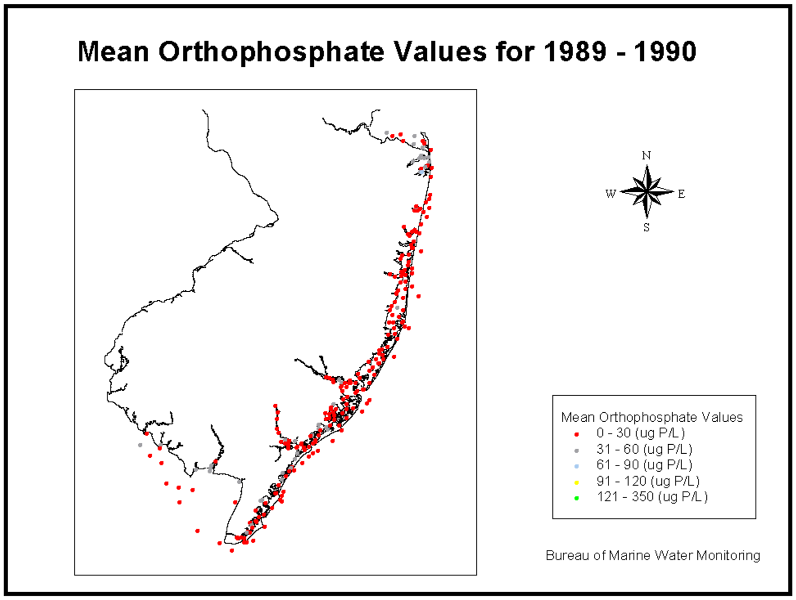


Figure 45: Orthophosphate (1989 - 1990)

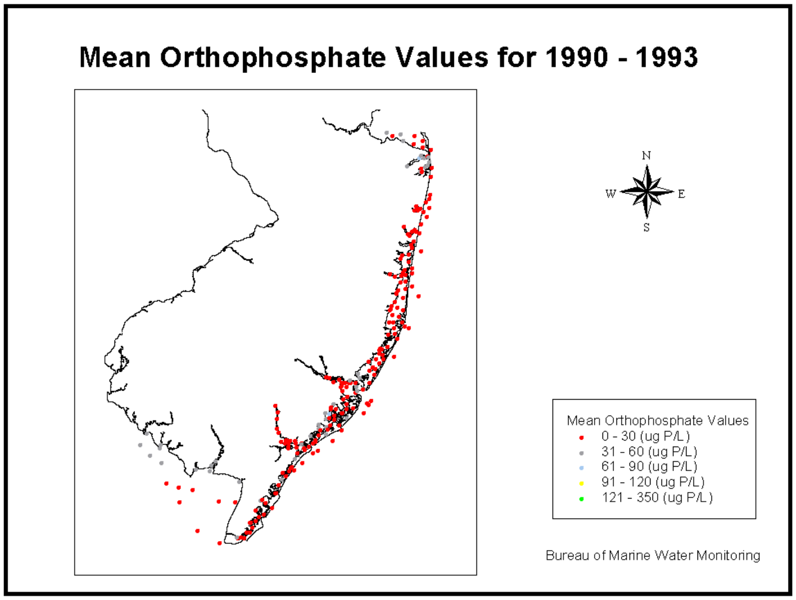


Figure 46: Orthophosphate (1990 - 1993)

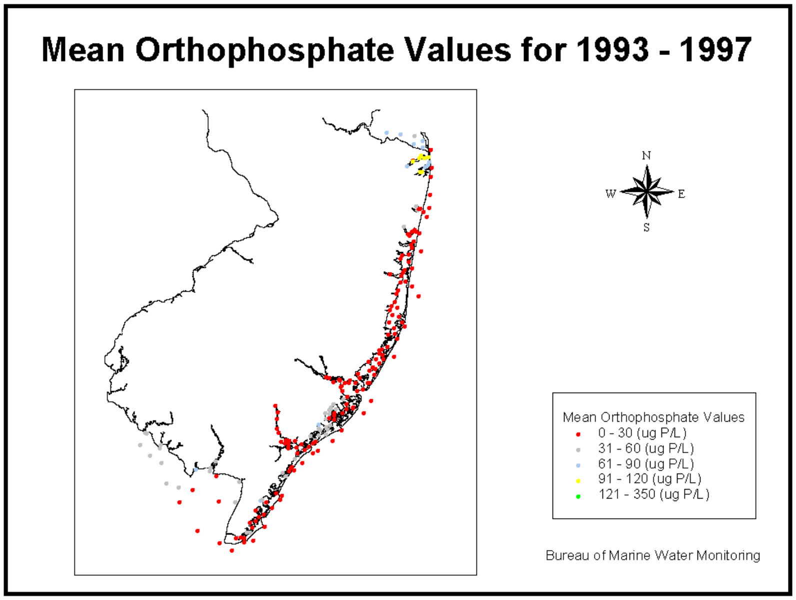


Figure 47: Orthophosphate (1993 - 1997)

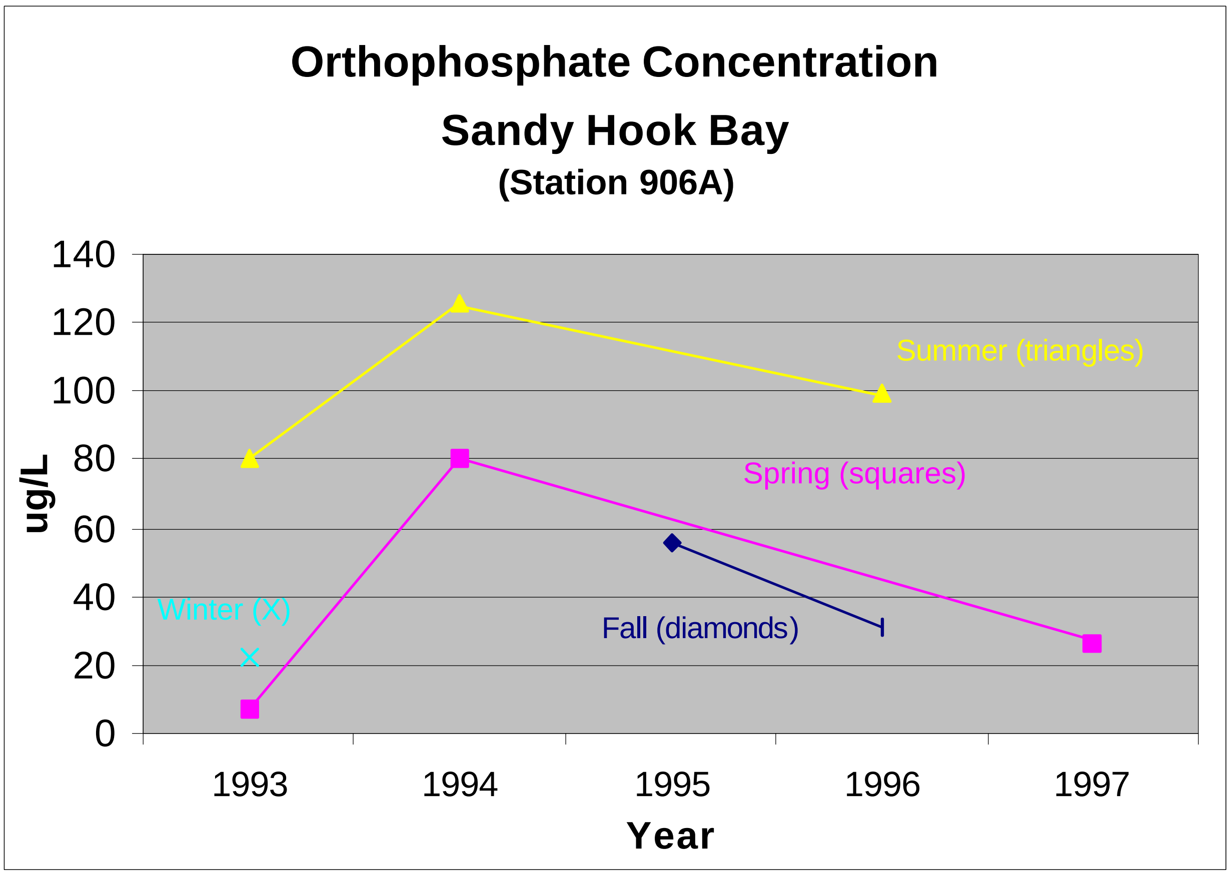


Figure 48: Orthophosphate-P in Sandy Hook Bay

While orthophosphate-P concentrations show some tendency toward a decrease in the Sandy Hook Bay area, the overall concentrations tend to be relatively high, with summer levels ranging to greater than 120 µg P/L and spring concentrations ranging to 80 µg P/L. These levels should be compared to levels measured in Barnegat Bay.

High levels of nutrients (both nitrogen and phosphorus) tend to stimulate warm weather blooms of nuisance algae in the Sandy Hook Bay / Raritan Bay area.

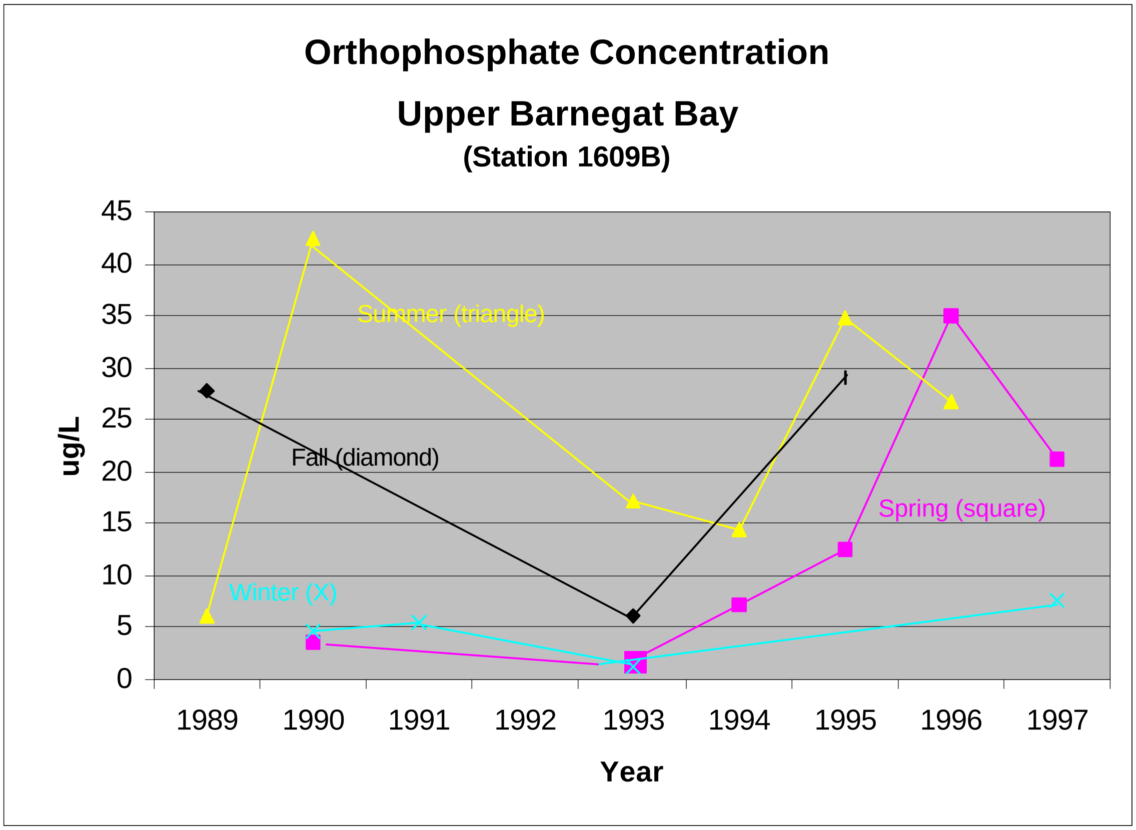


Figure 49: Orthophosphate Concentration (Station 1609B) – Barnegat Bay

In contrast to levels measured in Sandy Hook and Raritan Bays, orthophosphate-P concentrations measured in Barnegat Bay are significantly lower, with maximum values approximating 35 – 45 µg P/L. In addition, the difference between summer values and the remainder of the year is somewhat less.

However, these two sampling stations, both located in the northern part of Barnegat Bay, still exhibit elevated nutrient levels and summertime algal blooms are commonly observed.

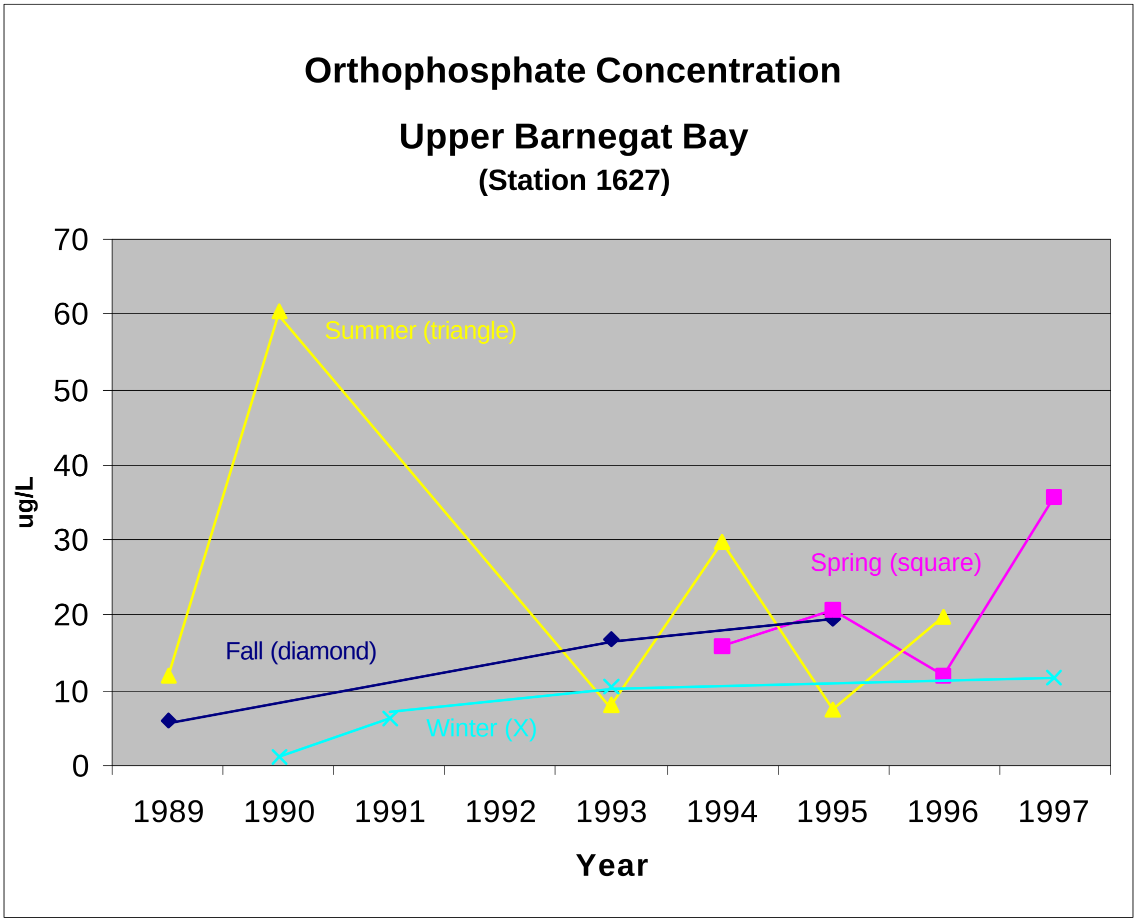


Figure 50: Orthophosphate Concentration (Station 1627) – Barnegat Bay

DISCUSSION

Factors Affecting the Concentration of Dissolved Oxygen

The concentration of oxygen in water is affected by numerous factors that are relatively independent of the concentration of pollutants in the water. These factors include temperature, salinity, and aeration (which includes incorporation of oxygen into the water by mechanical means).

In addition, the concentration may be affected by non-anthropogenic inputs. For example, water leaving a tidal wetland during the ebb tide frequently has a relatively low measured level of dissolved oxygen as a result of oxygen loss in shallow water on the wetland. This slug of poorly oxygenated water can then impact biota in the estuary.

Warmer water tends to have lower levels of dissolved oxygen, simply because the solubility of oxygen in water decreases as the temperature increases. Poorly agitated water also tends to have a lower concentration of dissolved oxygen, since agitation tends to incorporate oxygen into the water through mechanical means.

Biological processes also significantly affect the concentration of dissolved oxygen. For example, photosynthesis increases the concentration while respiratory processes decrease concentrations.

While evaluation of concentration is often appropriate in determining biological stress to aquatic biota, it can not account for the differences in solubility of the gas in water.

Therefore, while dissolved oxygen is frequently expressed as concentration (mg/L), it is often useful to evaluate oxygen data as the percent saturation. Expressing the relative amount of oxygen dissolved in the water in this way accounts for the differences in solubility based on temperature and, to a lesser extent, salinity.

Factors Affecting the Concentration of Nutrients

In many waterbodies the primary factors controlling the concentration of nutrients tend to be the input from anthropogenic sources and the uptake of nutrients through primary productivity. Related factors include loss of nutrients from tissue to the water column through senescence, incorporation of both inorganic and organic nutrient species into the sediments, resuspension from the sediments, and fixation of nitrogen gas from the atmosphere. Nitrogen species may be altered through nitrification or denitrification.

Relationship between Dissolved Oxygen and Nutrients

Since the concentration of dissolved oxygen is dependent in part of the rates of photosynthesis (which is a measure of primary productivity) and respiration, there is a significant relationship between nutrient levels and dissolved oxygen levels.

Higher levels of nutrients tend to stimulate primary productivity, at least to the extent that the levels of nutrients reflect the rate of incorporation into algal tissue. As the rate of primary productivity increases, the level of dissolved oxygen in the water column increases significantly, particularly during the daylight hours. During the night, when photosynthetic activity is minimal, respiratory processes tend to significantly decrease the level of oxygen in the water column. This diurnal pattern (high concentration during the day and low concentration during the night) is typical of waters where nutrient levels are elevated.

In addition, as the biomass increases, particularly during an algal bloom, the number of cells that are dying and decomposing also significantly increases. Decomposition utilizes oxygen, thus lowering the oxygen levels. This process frequently results in very low levels of oxygen in the water column and, consequently, death of other organisms such as fish or invertebrates.

Relationship between Nitrogen and Phosphorus Concentrations

Both nitrogen and phosphorus are needed as nutrients for primary productivity. Generally, algae incorporate nitrogen and phosphorus into tissue in a ratio of approximately 14:1. The ratio varies somewhat from one group of algae to another. However, it is relatively rare that any of the nutrients are found in the ecosystem in exactly the proportion needed for efficient algal uptake.

The ratio between measured concentrations of nitrogen and phosphorus is frequently used to estimate the propensity for primary productivity in a waterbody to be limited by one or the other nutrient.

When the ratio (with concentrations expressed as Nitrogen or Phosphorus, i.e., adjusted to account for the atomic weights of each contributing compound) is less than approximately 14:1, the waterbody is said to be "nitrogen limited". This means that it is likely that additional inputs of inorganic nitrogen compounds, such as ammonia-N or nitrate-N, will result in increased primary productivity.

When the ratio (with concentrations expressed as Nitrogen or Phosphorus, i.e., adjusted to account for the atomic weights of each contributing compound) is greater than approximately 14:1, the waterbody is said to be "phosphorus limited". This means that it is likely that additional inputs of inorganic phosphorus compounds, usually orthophosphate-P, will result in increased primary productivity.

This provides a simple way to evaluate the propensity of an area to be stimulated into excessive productivity (algal bloom).

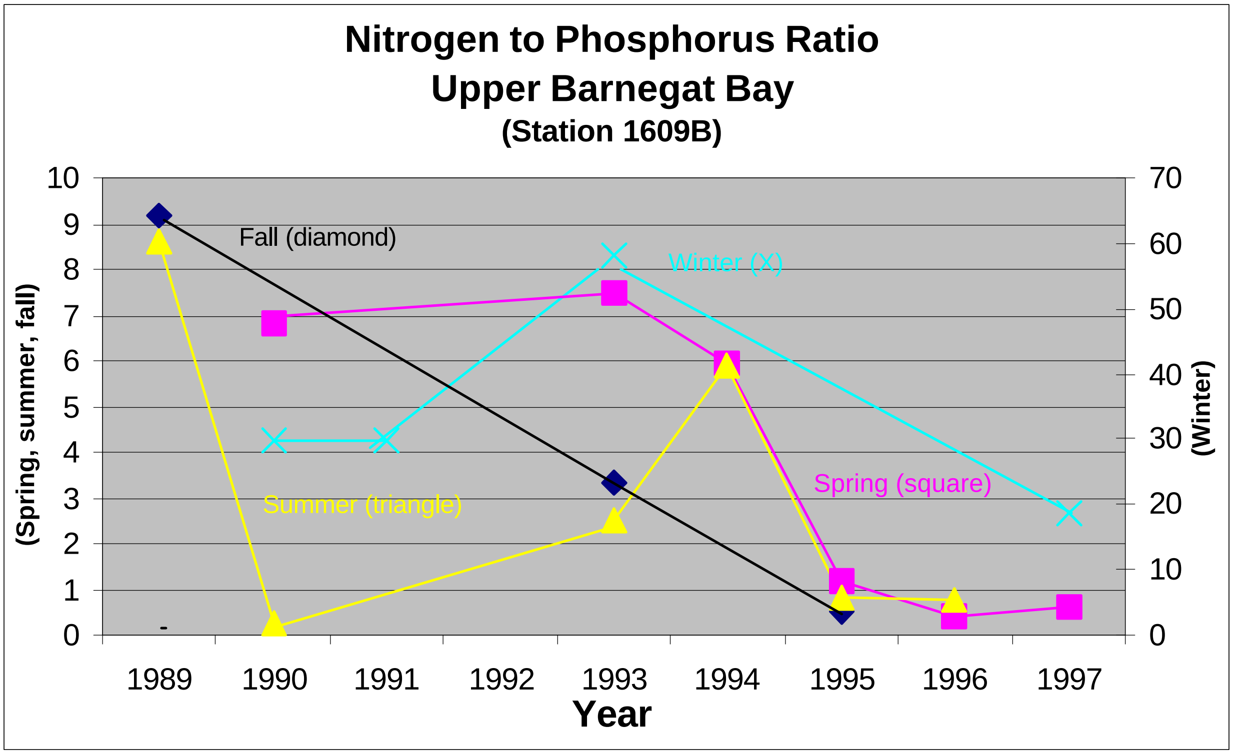


Figure 51: N:P Ratio Trend – Upper Barnegat Bay (Station 1609B)

An example of this relationship can be seen in the data from two stations in Barnegat Bay. Station 1609B is located in the Bay near Kettle Creek. Station 1627 is located in the Bay between Silver Bay and Toms River.

For each of these stations, the N:P ratio during warm weather months is usually less than 10, with relatively high orthophosphate-P concentrations. During the warm weather, algal blooms are frequently observed, particularly during the spring. The algal blooms are likely constrained by the relatively low NH_3-N + NO_3-N concentrations. Therefore, during the warm weather months, addition of nitrogen compounds would further stimulate algal growth. During the winter when biological uptake is at a minimum, the N:P ratio at Station 1609B is often greater than 50, while the ratio at Station 1627 tends to remain somewhat lower.

This pattern (nitrogen limitation in warm weather and phosphorus limitation during the winter) is not unique to the upper regions of Barnegat Bay, but is typical of the nutrient dynamics throughout the estuarine waters of New Jersey. The pattern is most pronounced in those areas with relatively high concentrations of nitrogen and/or phosphorus.

While the sources of the elevated nutrient levels can not be identified at this time, the interaction between nitrogen, phosphorus, and algal stimulation provide an insight into potential ways to improve water quality.

In this case, reduction of nutrient inputs would be likely to reduce algal blooms during warm weather. Reduction of algal blooms in turn would be likely to reduce the tendency toward periods of low oxygen conditions.

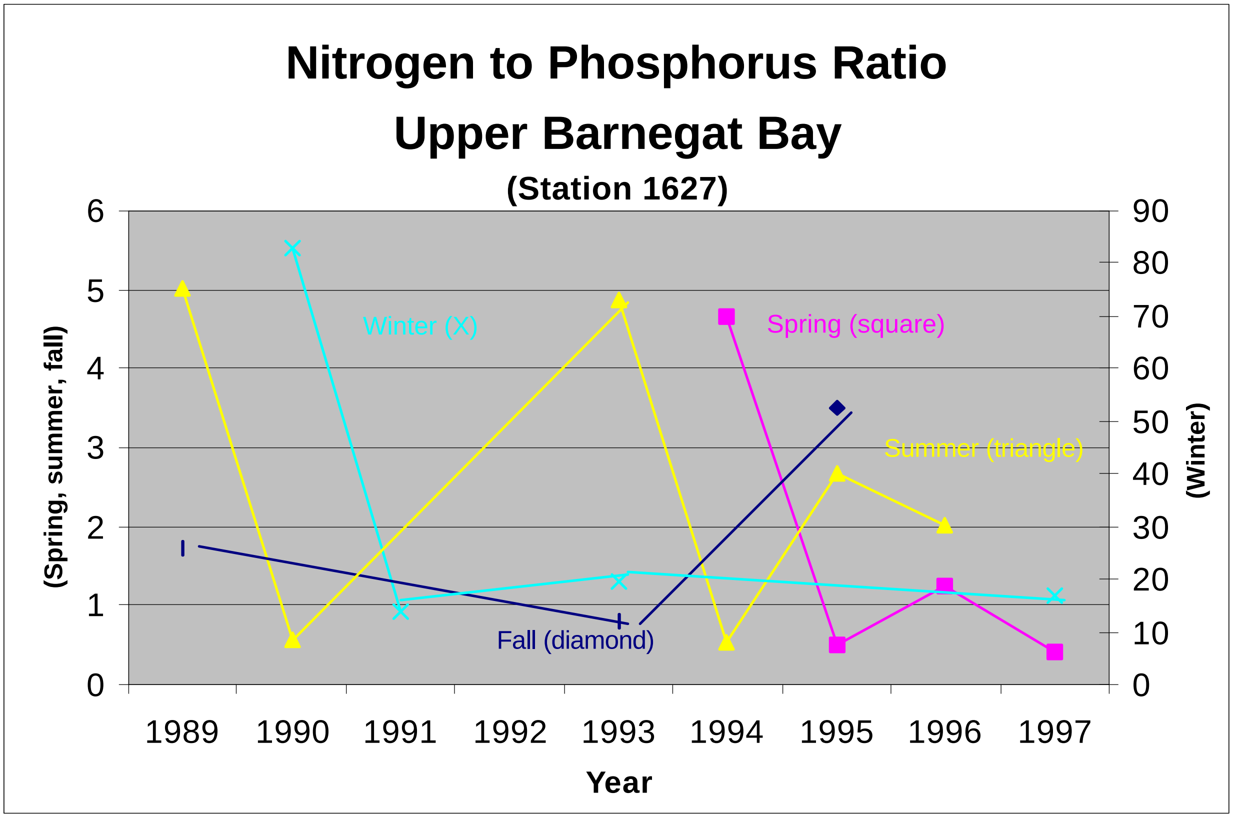


Figure 52: N:P Ratio (Station 1627)

CONCLUSIONS / RECOMMENDATIONS

Trends (1989 – 1997)

Nutrient concentrations in the coastal waters of New Jersey appear to be decreasing. This trend applies throughout all seasons in most of the coastal waters.

However, this pattern is complicated by significant differences between warm and cold weather and by missing samples during winter months in some areas. (Generally, the concentration is greatest during the winter months for both nitrogen and phosphorus.)

The concentration of dissolved oxygen in the coastal waters, particularly during the summer, has significantly worsened. There is not yet sufficient data to determine the potential causes of this pattern, although it is likely to be due in part to increased algal productivity.

Areas of Concern

The most significant change in water quality during the period of record for this estuarine monitoring program is the decrease in dissolved oxygen concentration in the area between Little Egg Harbor and Great Egg Harbor. In this area the minimum dissolved oxygen during warm weather is frequently less than 4.0 mg/L.

It is likely that this decrease is due to a combination of the following factors:

- Shallow water throughout the area, which is warmed more quickly and to a greater extent that deeper water

- Slightly elevated water temperature throughout this area (due to warmer than usual summer weather)

- Increased primary productivity in the form of algal growth

While there is insufficient data at this time to determine which of these factors plays a dominant role in the decreased dissolved oxygen levels, it would be useful to design a monitoring program to further elucidate this issue. This might be an area where an academic thesis add to the body of scientific knowledge of dissolved oxygen dynamics in shallow estuaries.

Recommendations

Sampling

The current sampling plan (quarterly sampling throughout the area) should be continued. In addition, particularly in those areas where winter samples have been difficult to obtain, efforts should be made to collect winter samples at as many stations as feasible. It would also be useful to obtain additional summer samples during the periods when the estuaries are most biologically active.

As additional riverine samples are collected, these samples collected between the estuary and the freshwater sections of the rivers should provide insights into the relative amount of input with sources in upgradient anthropogenic activities.

Data Sonde Deployment

Extra effort should be made to deploy data sondes capable of recording over at least a 24-hour period in those areas of significantly depleted oxygen levels. Areas of low oxygen to target include the area from Little Egg Harbor to Great Egg Harbor.

Although such data was available during a pervious report period, it was not available during this period.

Additional data would also be useful in evaluating areas of relatively high nutrients (such as the Delaware Bay and

Raritan / Sandy Hook Bay) where oxygen levels do not appear to be as significantly affected.

Correlation with Phytoplankton Surveys

Further effort should be made to correlate the results of the phytoplankton surveys conducted semi-weekly during the summer with nutrient levels in the coastal waters. While general statement can be made regarding those areas where phytoplankton blooms have occurred, the algal survey data could be used to better understand the potnetial interrelationships among the nutreint species and algal blooms.

Identification of Pollutant Sources

In several cases it appears that a major source of nutrients may be from upgradient areas. (See the discussion on the Great Egg Harbor.) Since there are no identified point sources in this area (e.g. a sewage treatment facility), the sources are likely to be nonpoint sources such as agricultural or storm water inputs. However, there is little quantifiable information to relate the measured water column concentrations to verified application of fertilizer and/or quantified storm water discharges. This information will be needed if efforts are to be made to reduce the input of nutrients into these waters.

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APPENDIX I. SAMPLING STATIONS

Appendix I lists sampling stations used to produce the data included in this report. It includes:

- Station number
- Station name
- Station latitude and longitude
- Station estuary type classification

Stations are listed in ascending order by station number. Latitude and longitude are listed as follows: digits 1-2: degrees; digits 3-4: minutes; digits 5-6: seconds.

STATION	LOCATION	CATEGORY	LATITUDE	LONGITUDE
1000E	NAVESINK RIVER	Estuarine - river dominated	402052	740454
1006	NAVESINK RIVER	Estuarine - river dominated	402211	740309
1006B	NAVESINK RIVER	Estuarine - river dominated	402159	740309
1012B	NAVESINK RIVER	Estuarine - river dominated	402241	740127
1014	NAVESINK RIVER	Estuarine - river dominated	402317	740054
1016	NAVESINK RIVER	Estuarine - river dominated	402241	735946
1016A	NAVESINK RIVER	Estuarine - river dominated	402244	735950
1020	NAVESINK RIVER	Estuarine - river dominated	402306	735854
1020B	NAVESINK RIVER	Estuarine - river dominated	402258	735848
1100A	SHREWSBURY RIVER	Estuarine - river dominated	402154	735835
1103B	SHREWSBURY RIVER	Estuarine - river dominated	402115	735840
1104B	SHREWSBURY RIVER	Estuarine - river dominated	402110	735901
1111B	SHREWSBURY RIVER	Estuarine - river dominated	402048	735945
1118A	SHREWSBURY RIVER	Estuarine - river dominated	402023	740055
1127A	SHREWSBURY RIVER	Estuarine - river dominated	401932	740113
1132	SHREWSBURY RIVER	Estuarine - river dominated	401940	740037
1201A	SHARK RIVER	Estuarine - Shallow	401114	740114
1203A	SHARK RIVER	Estuarine - Shallow	401053	740152
1204C	SHARK RIVER	Estuarine - Shallow	401056	740206
1206C	SHARK RIVER	Estuarine - Shallow	401049	740238
1215E	SHARK RIVER	Estuarine - Shallow	401119	740146
1216A	SHARK RIVER	Estuarine - Shallow	401139	740208
1217A	SHARK RIVER	Estuarine - Shallow	401147	740216
1300A	MANASQUAN INLET	Inlet	400609	740209
1303	MANASQUAN RIVER	Estuarine - river dominated	400634	740243
1306A	MANASQUAN RIVER	Estuarine - river dominated	400603	740326
1308A	MANASQUAN RIVER	Estuarine - river dominated	400529	740407
1308C	MANASQUAN RIVER	Estuarine - river dominated	400515	740404
1309A	MANASQUAN RIVER	Estuarine - river dominated	400531	740443
1314A	MANASQUAN RIVER	River	400713	740550
1502A	TOMS RIVER	River	395558	740828
1506A	TOMS RIVER	River	395633	740958
1600D	BARNEGAT BAY	Estuarine - Shallow	400314	740347
1601B	BARNEGAT BAY	Estuarine - Shallow	400355	740307
1604A	BARNEGAT BAY	Estuarine - Shallow	400228	740320
1605A	BARNEGAT BAY	Estuarine - Shallow	400222	740323
1609B	BARNEGAT BAY	Estuarine - Shallow	400103	740424
1613A	BARNEGAT BAY	Estuarine - Shallow	400048	740616

STATION	LOCATION	CATEGORY	LATITUDE	LONGITUDE
1617E	BARNEGAT BAY	Estuarine - Shallow	395922	740428
1618A	BARNEGAT BAY	Estuarine - Shallow	395958	740652
1622E	BARNEGAT BAY	Estuarine - Shallow	395829	740445
1627	BARNEGAT BAY	Estuarine - Shallow	395723	740539
1629	BARNEGAT BAY	Estuarine - Shallow	395705	740641
1629B	BARNEGAT BAY	Estuarine - Shallow	395653	740607
1631E	BARNEGAT BAY	Estuarine - Shallow	395621	740529
1632B	BARNEGAT BAY	Estuarine - Shallow	395615	740638
1635E	BARNEGAT BAY	Estuarine - Shallow	395449	740528
1636A	BARNEGAT BAY	Estuarine - Shallow	395440	740658
1645C	BARNEGAT BAY	Estuarine - Shallow	395255	740736
1645G	BARNEGAT BAY	Estuarine - Shallow	395315	740521
1648A	BARNEGAT BAY	Estuarine - Shallow	395215	740801
1648B	BARNEGAT BAY	Estuarine - Shallow	395208	740803
1651D	BARNEGAT BAY	Estuarine - Shallow	395109	740609
1653A	BARNEGAT BAY	Estuarine - Shallow	395024	740830
1661A	BARNEGAT BAY	Estuarine - Shallow	394930	740939
1661D	BARNEGAT BAY	Estuarine - Shallow	394906	740747
1661F	BARNEGAT BAY	Estuarine - Shallow	394835	740608
1662A	BARNEGAT BAY	Estuarine - river dominated	394850	740941
1663A	BARNEGAT BAY	Estuarine - Shallow	394839	741005
1670D	BARNEGAT BAY	Estuarine - Shallow	394548	741012
1670F	BARNEGAT BAY	Estuarine - Shallow	394547	740859
1674B	BARNEGAT BAY	Estuarine - Shallow	394433	740854
1675	BARNEGAT BAY	Estuarine - Shallow	394307	741025
1683C	BARNEGAT BAY	Estuarine - Shallow	394315	740833
1688A	BARNEGAT BAY	Inlet	394555	740617
1688B	BARNEGAT INLET	Inlet	394551	740630
1691A	BARNEGAT BAY	Estuarine - Shallow	394733	740913
1691E	BARNEGAT BAY	Estuarine - Shallow	394712	740730
1700A	MANAHAWKIN BAY	Estuarine - Shallow	394018	741051
1703	MANAHAWKIN BAY	Estuarine - Shallow	393955	741300
1703C	MANAHAWKIN BAY	Estuarine - Shallow	393939	741225
1704	MANAHAWKIN BAY	Estuarine - Shallow	393928	741308
1706	MILL CREEK	Estuarine - Shallow	393853	741313
1707C	MANAHAWKIN BAY	Estuarine - Shallow	393825	741220
1712	WESTECUNK CREEK	Estuarine - Shallow	393700	741614
1718B	LITTLE EGG HARBOR	Estuarine - Shallow	393635	741306
1718C	LITTLE EGG HARBOR	Estuarine - Shallow	393640	741320

STATION	LOCATION	CATEGORY	LATITUDE	LONGITUDE
1719E	LITTLE EGG HARBOR	Estuarine - Shallow	393731	741410
1721	LITTLE EGG HARBOR	Estuarine - Shallow	393730	741206
1800B	LITTLE EGG HARBOR	Estuarine - Shallow	393543	741506
1800D	LITTLE EGG HARBOR	Estuarine - Shallow	393521	741425
1818D	LITTLE EGG HARBOR	Estuarine - Shallow	393408	741930
1820A	LITTLE EGG HARBOR	Estuarine - Shallow	393314	741854
1823B	GREAT BAY	Estuarine - river dominated	393115	741954
1824A	LITTLE EGG INLET	Inlet	393041	741745
1824B	LITTLE EGG INLET	Inlet	393040	741752
1826A	LITTLE EGG HARBOR	Estuarine - Shallow	393207	741607
1826B	LITTLE EGG HARBOR	Estuarine - Shallow	393212	741627
1831	LITTLE EGG HARBOR	Estuarine - Shallow	393405	741440
1834A	LITTLE EGG HARBOR	Estuarine - Shallow	393453	741609
1900B	MULLICA RIVER	Estuarine - river dominated	393214	742409
1903	GREAT BAY	Estuarine - Shallow	393113	742427
1903E	GREAT BAY	Estuarine - Shallow	393115	742247
1903L	GREAT BAY	Estuarine - Shallow	393127	742416
1906D	GREAT BAY	Estuarine - Shallow	393019	742358
1911A	GREAT BAY	Estuarine - Shallow	392953	742002
1911C	GREAT BAY	Estuarine - Shallow	393023	741937
1917A	GREAT BAY	Estuarine - Shallow	393211	742003
1921B	GREAT BAY	Estuarine - Shallow	393210	742136
1923B	GREAT BAY	Estuarine - Shallow	393210	742201
1924	GREAT BAY	Estuarine - Shallow	393244	742153
1927A	GREAT BAY	Estuarine - Shallow	393208	742311
2000A	MULLICA RIVER	Estuarine - river dominated	393240	742433
2002A	MULLICA RIVER	Estuarine - river dominated	393251	742451
2005	MULLICA RIVER	Estuarine - river dominated	393226	742633
2006A	MULLICA RIVER	Estuarine - river dominated	393258	742647
2009A	MULLICA RIVER	Estuarine - river dominated	393319	742743
2011A	MULLICA RIVER	River	393324	742848
2100A	GREAT BAY	Estuarine - Shallow	392859	742225
2101A	LITTLE BAY	Estuarine - Shallow	392825	742346
2102B	LITTLE BAY	Estuarine - Shallow	392726	742252
2106A	LITTLE BAY	Estuarine - Shallow	392613	742252
2108	LITTLE BAY	Estuarine - Shallow	392635	742055
2108A	LITTLE BAY	Estuarine - Shallow	392629	742055
2202A	LITTLE BAY	Estuarine - river dominated	392524	742405
2202B	LITTLE BAY	Estuarine - Shallow	392521	742355

STATION	LOCATION	CATEGORY	LATITUDE	LONGITUDE
2215A	LITTLE BAY	Estuarine - Shallow	392415	742241
2301	REED BAY	Estuarine - Shallow	392727	742630
2305C	REED BAY	Estuarine - Shallow	392614	742548
2306C	REED BAY	Estuarine - Shallow	392637	742717
2307B	REED BAY	Estuarine - Shallow	392621	742721
2308	REED BAY	Estuarine - Shallow	392609	742743
2310D	REED BAY	Estuarine - Shallow	392527	742632
2311	REED BAY	Estuarine - Shallow	392520	742627
2311D	REED BAY	Estuarine - Shallow	392446	742617
2400A	ABSECON BAY	Estuarine - Shallow	392505	742740
2401	ABSECON CREEK	Estuarine - Shallow	392517	742855
2405B	ABSECON BAY	Estuarine - Shallow	392405	742850
2408A	ABSECON BAY	Estuarine - Shallow	392414	742740
2412A	ABSECON BAY	Estuarine - Shallow	392355	742619
2412B	ABSECON BAY	Estuarine - Shallow	392353	742621
2416F	ABSECON INLET	Inlet	392239	742453
2420	BEACH THOROFARE	Estuarine - Shallow	392230	742731
2503	LAKES BAY	Estuarine - Shallow	392212	742840
2507A	LAKES BAY	Estuarine - Shallow	392244	743050
2510A	LAKES BAY	Estuarine - Shallow	392148	743045
2511A	LAKES BAY	Estuarine - Shallow	392127	743022
2520	LAKES BAY	Estuarine - Shallow	391916	743150
2522A	GREAT EGG INLET	Inlet	391852	743147
2524	BEACH THOROFARE	Estuarine - Shallow	392017	743050
2533	BEACH THOROFARE	Estuarine - Shallow	392139	742809
2536	INSIDE THOROFARE	Estuarine - Shallow	392030	742843
2602B	SCULL BAY	Estuarine - Shallow	392020	743250
2604A	SCULL BAY	Estuarine - Shallow	392015	743315
26A	RARITAN BAY	Estuarine - river dominated	402830	741040
2700	GREAT EGG INLET	Inlet	391827	743235
2701B	GREAT EGG INLET	Inlet	391750	743343
2712	GREAT EGG HARBOR	Estuarine - Shallow	391826	743557
2712A	GREAT EGG HARBOR	Estuarine - Shallow	391822	743552
2713A	GREAT EGG HARBOR	Estuarine - Shallow	391732	743513
2713B	GREAT EGG HARBOR	Estuarine - Shallow	391727	743511
2714A	GREAT EGG HARBOR	Estuarine - Shallow	391703	743458
2720	GREAT EGG HARBOR	Estuarine - Shallow	391744	743708
2720B	GREAT EGG HARBOR	Estuarine - Shallow	391731	743715
2801	GREAT EGG RIVER	Estuarine - river dominated	391906	743917

STATION	LOCATION	CATEGORY	LATITUDE	LONGITUDE
2801A	GREAT EGG RIVER	Estuarine - river dominated	391903	743921
2804	GREAT EGG RIVER	River	391917	744027
2804A	GREAT EGG RIVER	River	391914	744031
2812	GREAT EGG RIVER	River	392050	744232
2814A	GREAT EGG RIVER	River	392153	744259
2821B	GREAT EGG RIVER	River	392407	744307
2822A	GREAT EGG RIVER	River	392530	744251
2827A	GREAT EGG RIVER	River	392654	744328
2863B	PATCONG CREEK	Estuarine - river dominated	391902	743745
2864B	PATCONG CREEK	Estuarine - river dominated	391826	743733
2900	MIDDLE RIVER	Estuarine - river dominated	391829	743942
2900A	MIDDLE RIVER	Estuarine - river dominated	391824	744040
2900E	MIDDLE RIVER	Estuarine - river dominated	391847	744155
2901	TUCKAHOE RIVER	Estuarine - river dominated	391754	743936
2901A	TUCKAHOE RIVER	Estuarine - river dominated	391750	743937
2902A	TUCKAHOE RIVER	Estuarine - river dominated	391723	743934
3002A	PECK BAY	Estuarine - Shallow	391617	743708
3007A	PECK BAY	Estuarine - Shallow	391504	743743
3007A-FIELDREP		Estuarine - river dominated		
3007A-FIELDSPK		Estuarine - river dominated		
3101A	CORSON INLET	Inlet	391311	743844
3103A	CORSON INLET	Inlet	391256	743900
3105A	CORSON INLET	Inlet	391214	743919
3115	LUDLAM BAY	Estuarine - Shallow	391154	744119
3122A	LUDLAM BAY	Estuarine - Shallow	391111	744016
3127C	LUDLAM BAY	Estuarine - Shallow	391016	744130
3201	LUDLAM BAY	Estuarine - Shallow	390901	744231
3214B	TOWNSEND INLET	Inlet	390714	744305
3215A	TOWNSEND INLET	Inlet	390708	744320
3307B	GREAT SOUND	Estuarine - Shallow	390532	744746
3307N	GREAT SOUND	Estuarine - Shallow	390540	744707
3310A	GREAT SOUND	Estuarine - Shallow	390358	744420
3312	GREAT SOUND	Estuarine - Shallow	390504	744614
3312A	GREAT SOUND	Estuarine - Shallow	390505	744606
3403C	HEREFORD INLET	Inlet	390218	744646
3409H	JENKINS SOUND	Estuarine - Shallow	390324	744910
3411E	HEREFORD INLET	Inlet	390149	744809
3503B	RICHARDSON SOUND	Estuarine - Shallow	390034	745031

STATION	LOCATION	CATEGORY	LATITUDE	LONGITUDE
3504A	RICHARDSON SOUND	Estuarine - Shallow	390033	745047
3509B	GRASSY SOUND	Estuarine - Shallow	390050	744910
3509C	GRASSY SOUND	Estuarine - Shallow	390042	744858
3516	GRASSY SOUND	Estuarine - Shallow	385959	745020
3516C	RICHARDSON SOUND	Estuarine - Shallow	385931	744959
3602D	SUNSET LAKE	Estuarine - Shallow	385817	745046
3606A	JARVIS SOUND	Estuarine - Shallow	385831	745124
3607A	JARVIS SOUND	Estuarine - Shallow	385819	745146
3614A	CAPE MAY INLET	Inlet	385700	745226
3616B	CAPE MAY HARBOR	Estuarine - Shallow	385707	745317
3617A	CAPE MAY HARBOR	Estuarine - Shallow	385700	745413
3618	CAPE MAY CANAL	Estuarine - Shallow	385715	745432
3618A	CAPE MAY CANAL	Estuarine - Shallow	385704	745443
3800	DELAWARE BAY	Estuarine - river dominated	391530	751954
3801B	NANTUXENT COVE	Estuarine - river dominated	391754	751642
3803A	NANTUXENT COVE	Estuarine - river dominated	391712	751654
3826A	DELAWARE BAY	Estuarine - river dominated	385548	745924
3827	DELAWARE BAY	Estuarine - river dominated	385842	750600
3840A	MAURICE RIVER COVE	Estuarine - river dominated	391230	750630
3845G	DELAWARE BAY	Estuarine - river dominated	390506	751106
3845P	DELAWARE BAY	Estuarine - river dominated	390748	750718
3847B	MAURICE RIVER COVE	Estuarine - river dominated	391206	750230
3848B	MAURICE RIVER COVE	Estuarine - river dominated	391254	750218
3849B	DELAWARE BAY	Estuarine - river dominated	390824	751130
3868	DELAWARE BAY	Estuarine - river dominated	390918	751500
3874B	DELAWARE BAY	Estuarine - river dominated	391354	751630
3881	DELAWARE BAY	Estuarine - river dominated	391106	750036
3888	DELAWARE BAY	Estuarine - river dominated	390518	745942
3888I	DENNIS CREEK	Estuarine - river dominated	390948	745400
3895E	DELAWARE BAY	Estuarine - river dominated	390512	745500
3900A	MAURICE RIVER	River	391324	750200
3900M	MAURICE RIVER	River	391421	750045
4100	DELAWARE BAY	Estuarine - river dominated	391800	752248
4101A	COHANSEY COVE	Estuarine - river dominated	392048	752124
4101B	COHANSEY COVE	Estuarine - river dominated	392030	752054
63B	RARITAN BAY	Estuarine - river dominated	402746	740907
66	RARITAN BAY	Estuarine - river dominated	402811	740636
906A	SANDY HOOK BAY	Estuarine - river dominated	402515	740018
906C	SANDY HOOK BAY	Estuarine - river dominated	402608	735951

STATION	LOCATION	CATEGORY	LATITUDE	LONGITUDE
908C	SANDY HOOK BAY	Estuarine - river dominated	402640	740023
914	SANDY HOOK BAY	Estuarine - river dominated	402559	740248
918	SANDY HOOK BAY	Estuarine - river dominated	402741	740238
A101A	HEREFORD INLET	Inlet	385936	744630
A105A2	ATLANTIC OCEAN	Ocean near outfall	385630	744951
A107A	CAPE MAY INLET	Inlet	385606	745224
A110B	ATLANTIC OCEAN	Ocean	385418	745600
A11A	ATLANTIC OCEAN	Ocean near outfall	402031	735748
A13A	ATLANTIC OCEAN	Ocean near outfall	401830	735804
A17A2	ATLANTIC OCEAN	Ocean near outfall	401424	735818
A18A2	ATLANTIC OCEAN	Ocean near outfall	401330	735836
A19A	ATLANTIC OCEAN	Ocean	401242	735936
A20B	ATLANTIC OCEAN	Ocean near outfall	401125	735836
A21A	SHARK RIVER INLET	Inlet	401037	740013
A22B	ATLANTIC OCEAN	Ocean near outfall	400930	735912
A24A	ATLANTIC OCEAN	Ocean	400748	740106
A26A	MANASQUAN INLET	Inlet	400548	740130
A30B	ATLANTIC OCEAN	Ocean near outfall	400142	740106
A34A	ATLANTIC OCEAN	Ocean near outfall	395754	740324
A35A	ATLANTIC OCEAN	Ocean near outfall	395648	740330
A38A2	ATLANTIC OCEAN	Ocean near outfall	395343	740335
A40C	ATLANTIC OCEAN	Ocean	395130	740154
A47A	BARNEGAT INLET	Inlet	394448	740542
A47B	BARNEGAT INLET	Inlet	394430	740430
A54B	ATLANTIC OCEAN	Ocean near outfall	393800	740854
A65B	LITTLE EGG INLET	Inlet	392822	741606
A65B2	LITTLE EGG INLET	Inlet	392806	741536
A66B	LITTLE EGG INLET	Inlet	392734	741651
A66B2	LITTLE EGG INLET	Inlet	392712	741618
A68B	ATLANTIC OCEAN	Inlet	392542	741819
A68B2	ATLANTIC OCEAN	Inlet	392524	741748
A74A	ABSECON INLET	Inlet	392130	742412
A77B	ATLANTIC OCEAN	Ocean near outfall	391900	742654
A7A	ATLANTIC OCEAN	Ocean near outfall	402436	735757
A81B	GREAT EGG INLET	Inlet	391654	743106
A82A2	GREAT EGG INLET	Inlet	391618	743233
A83A2	ATLANTIC OCEAN	Ocean	391530	743336
A85A2	ATLANTIC OCEAN	Ocean near outfall	391403	743539
A87A	CORSON INLET	Inlet	391218	743806

STATION	LOCATION	CATEGORY	LATITUDE	LONGITUDE
A92A2	TOWNSEND INLET	Inlet	390730	744103
A93A2	TOWNSEND INLET	Inlet	390636	744133
A94A	ATLANTIC OCEAN	Ocean near outfall	390542	744206
A94A2	ATLANTIC OCEAN	Ocean near outfall	390524	744136
AX50A1	ATLANTIC OCEAN	Ocean	394212	740748
C106A1	ATLANTIC OCEAN	Inlet	385600	745148
R01	SWIMMING RIVER	River		
R08	METEDECONK RIVER	Tidal Tributary		
R09	KETTLE CREEK	Tidal Tributary		
R10	SILVER BAY	Tidal Tributary		
R10A	SILVER BAY	Tidal Tributary		
R11	TOMS RIVER	Estuarine - river dominated		
R12	CEDAR CREEK	Tidal Tributary		
R13	FORKED RIVER	Tidal Tributary		
R15	OYSTER CREEK	Tidal Tributary		
R16	WARETOWN CREEK	Tidal Tributary		
RB3	RARITAN BAY	Estuarine - river dominated	402635	740557
RB5	RARITAN BAY	Estuarine - river dominated		

APPENDIX II. SAMPLING STATION LOCATION

The following maps show the sampling locations for the sampling stations described in Appendix I. They are ordered beginning in Raritan Bay, proceeding south toward Cape May, and thence northwest into the Delaware Bay.

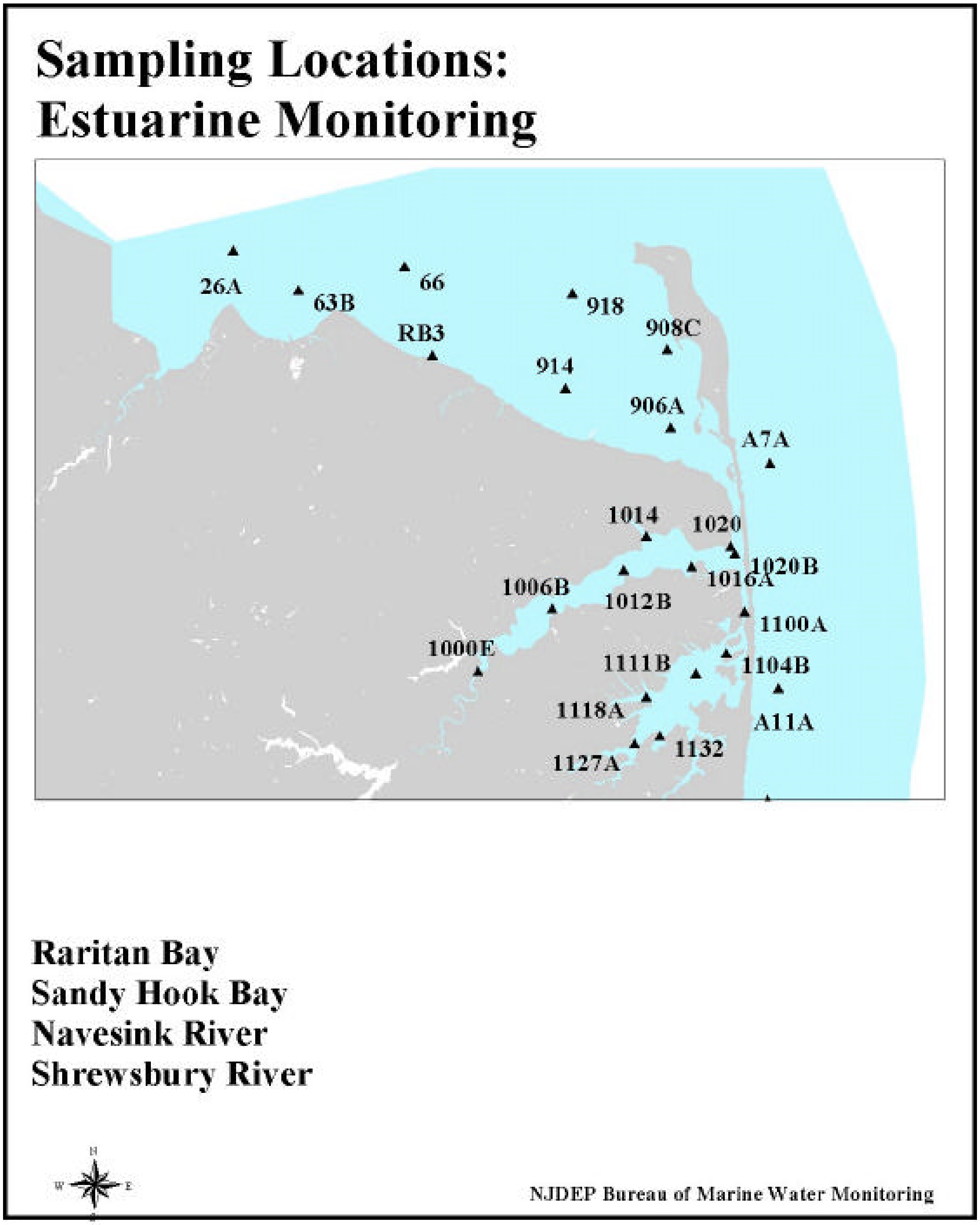

Figure 53: Sampling Stations in the vicinity of Raritan Bay

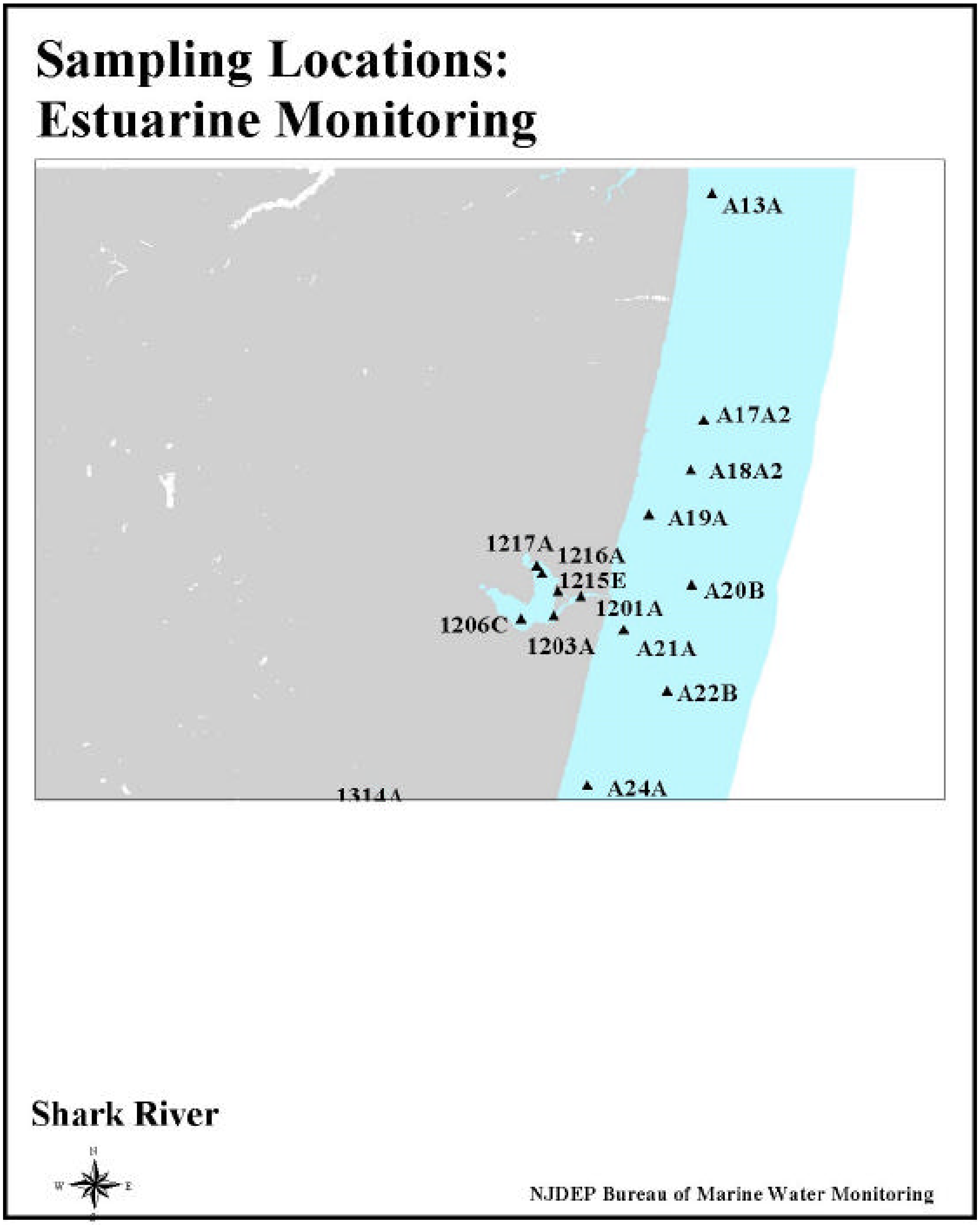

Figure 54: Sampling Stations in the vicinity of Shark River

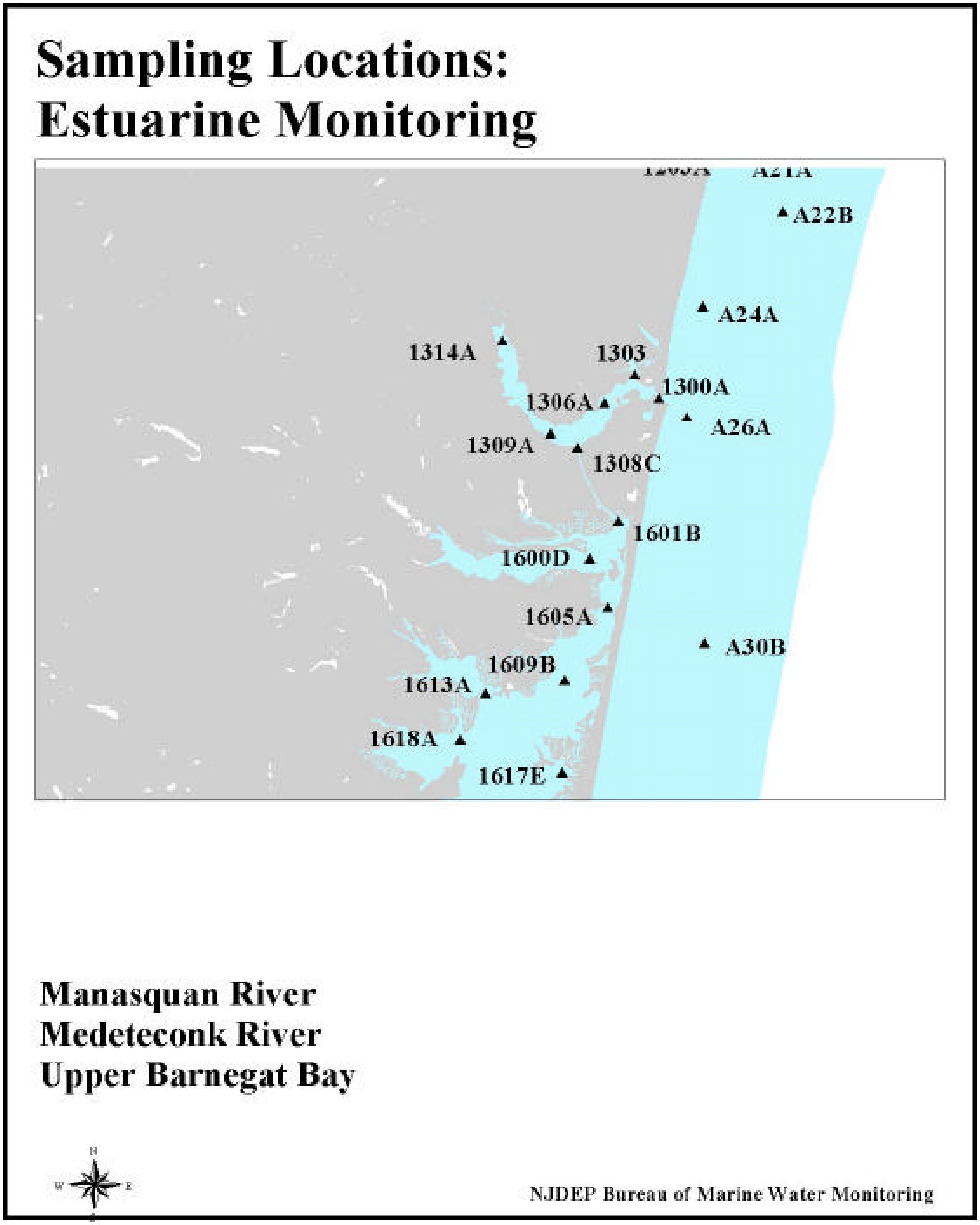

Figure 55: Sampling Stations in the vicinity of the Manasquan River

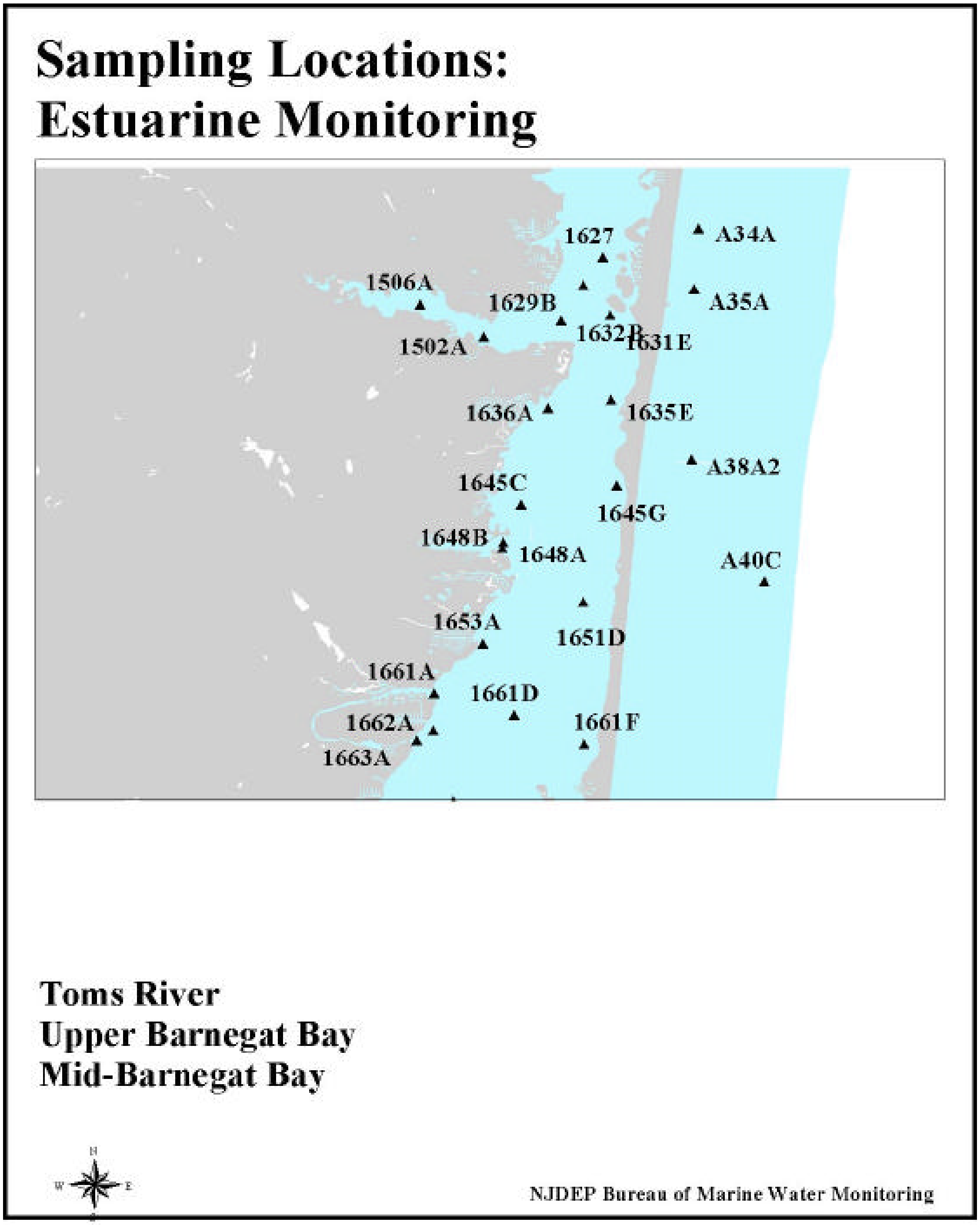

Figure 56: Sampling Stations in the vicinity of the Toms River

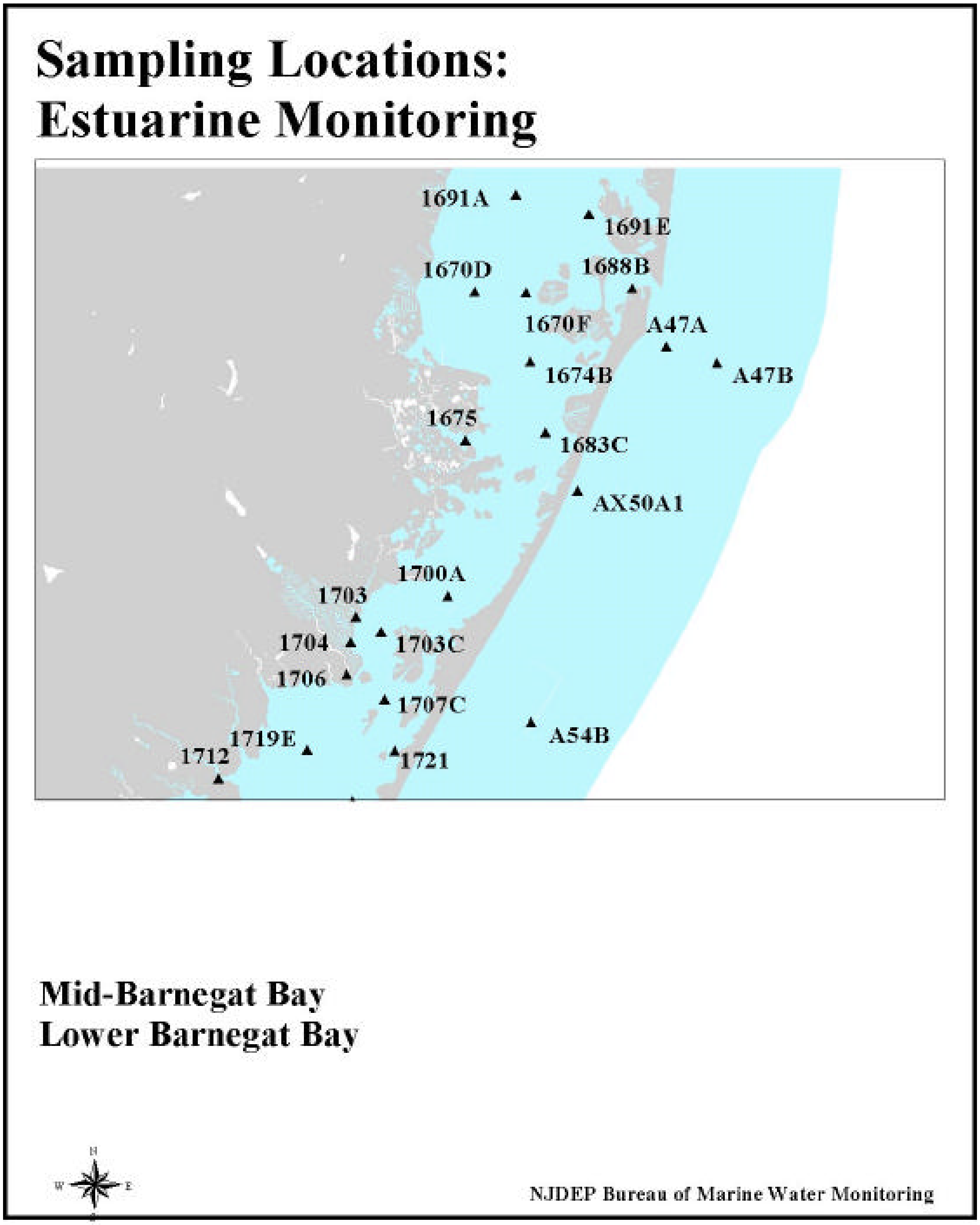

Figure 57: Sampling Stations in the vicinity of Barnegat Inlet

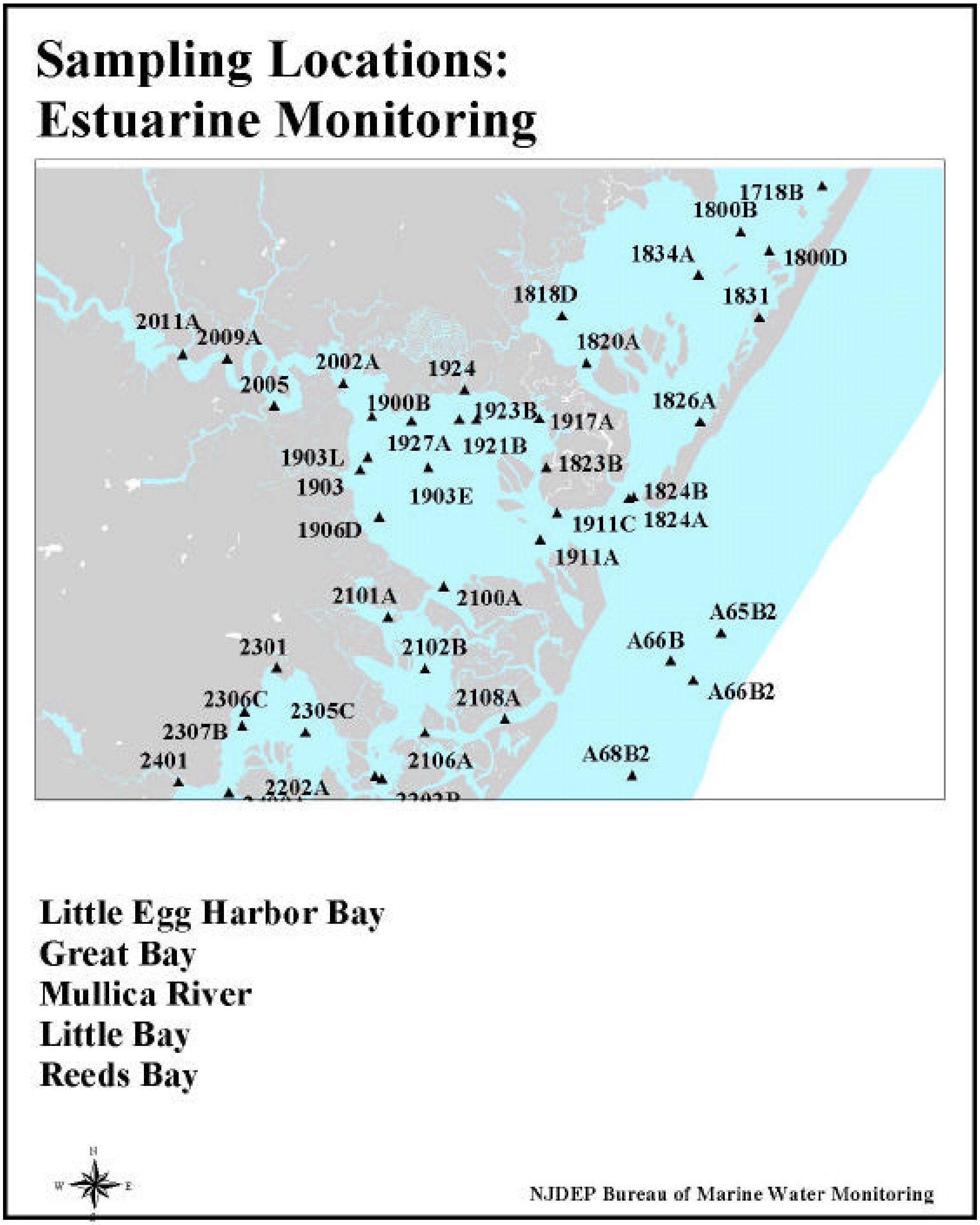

Figure 58: Sampling Stations in the vicinity of the Mullica River

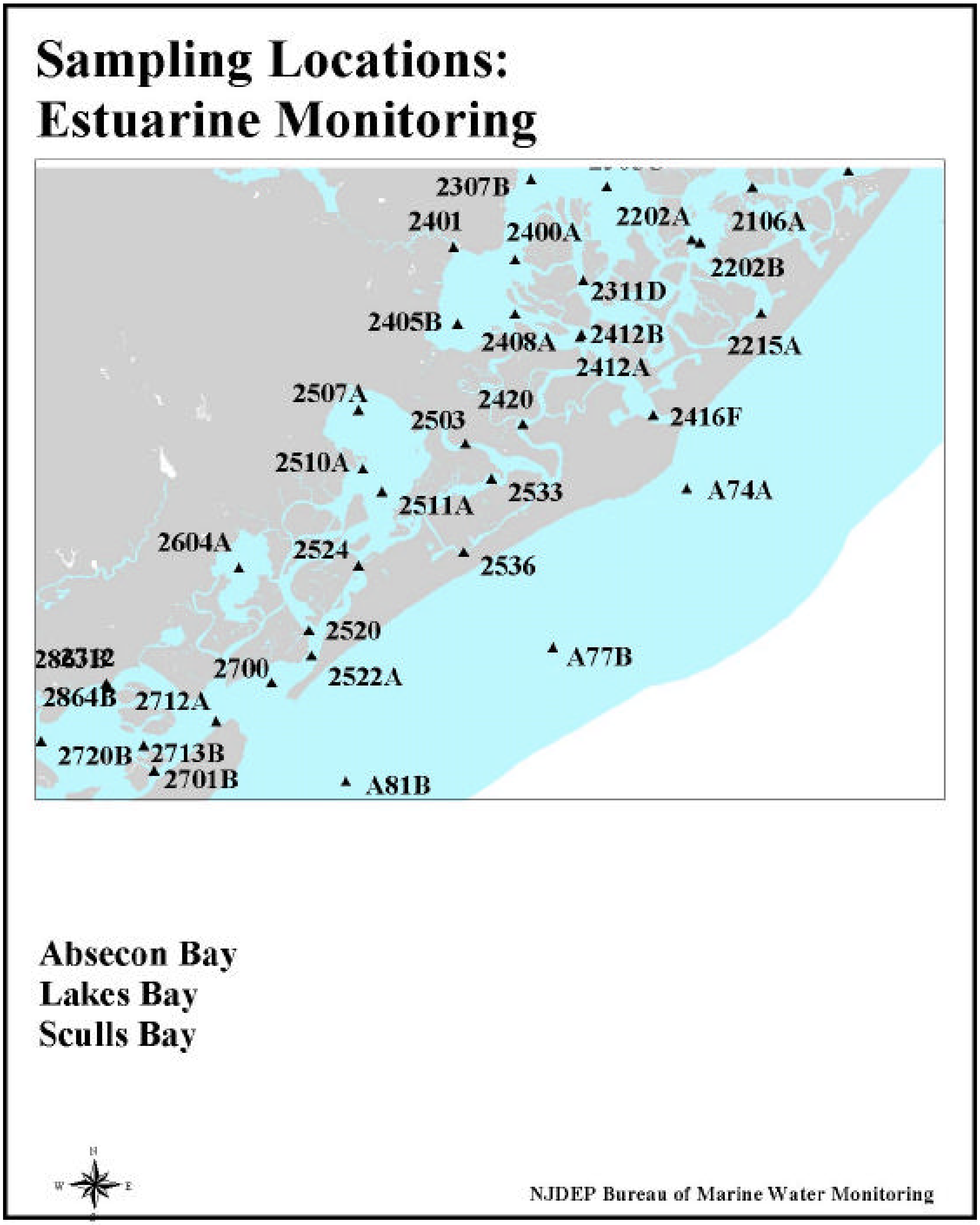

Figure 59: Sampling Stations in the vicinity of Absecon Inlet

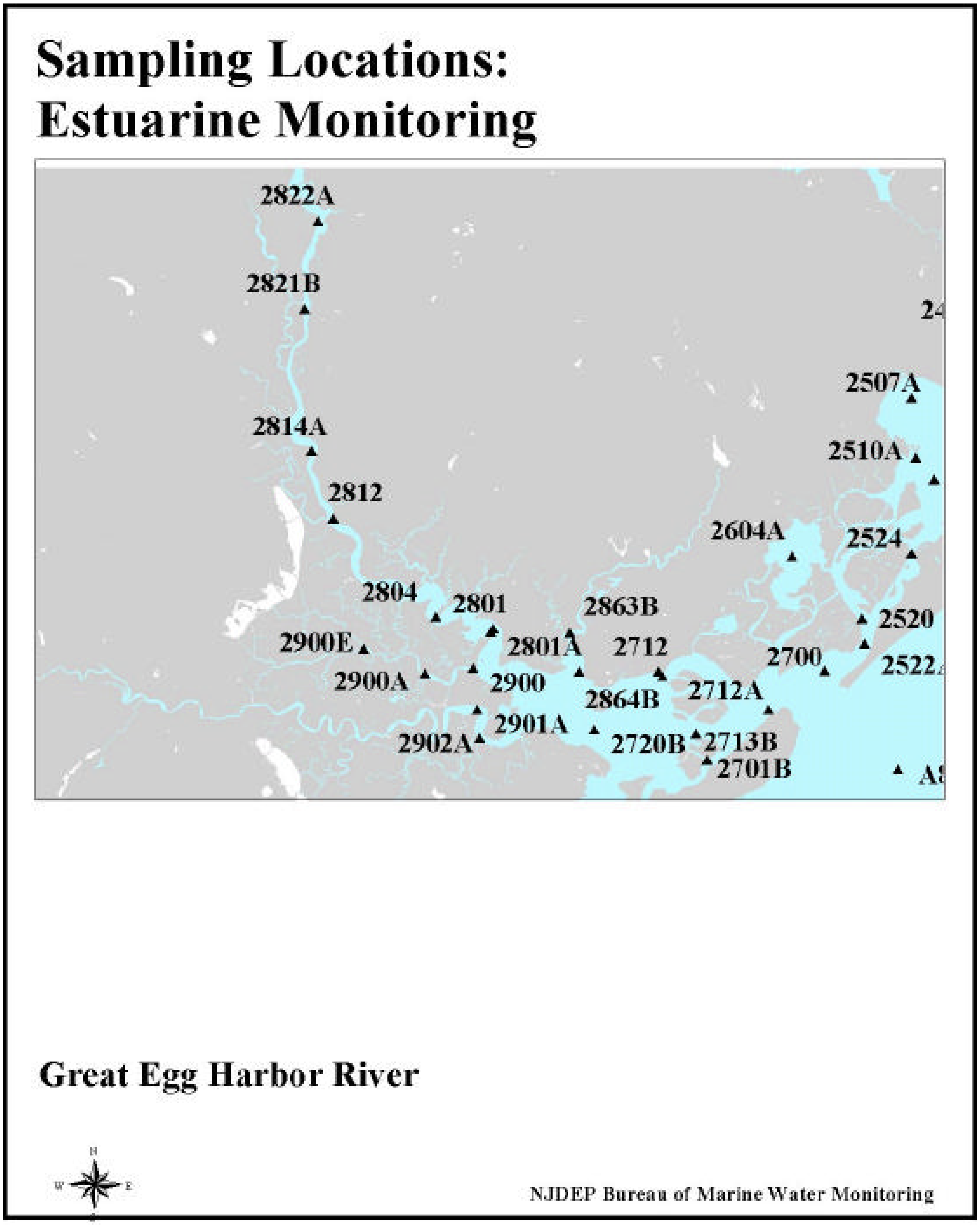

Figure 60: Sampling Stations in the vicinity of Great Egg Inlet

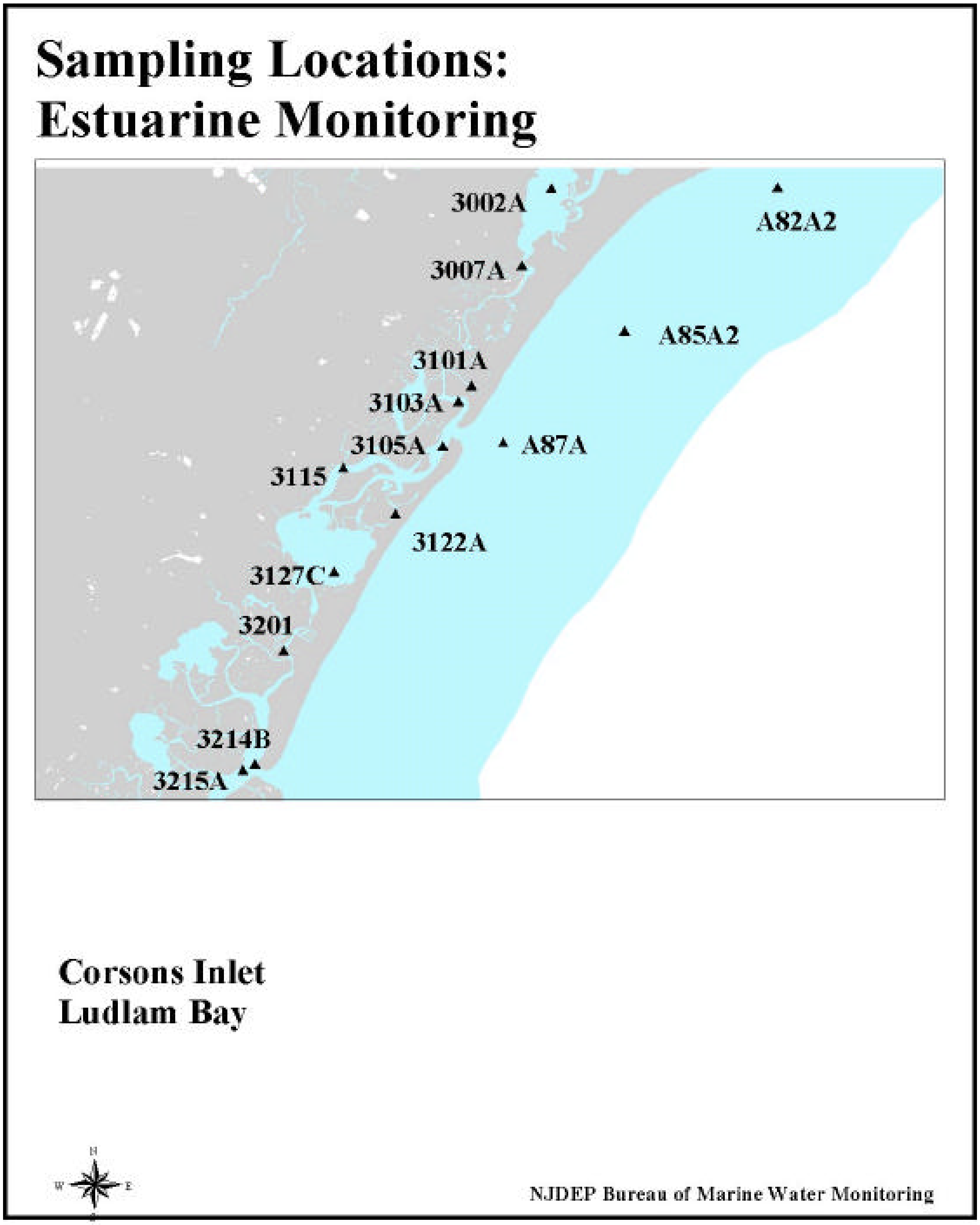

Figure 61: Sampling Stations in the vicinity of Townsends Inlet

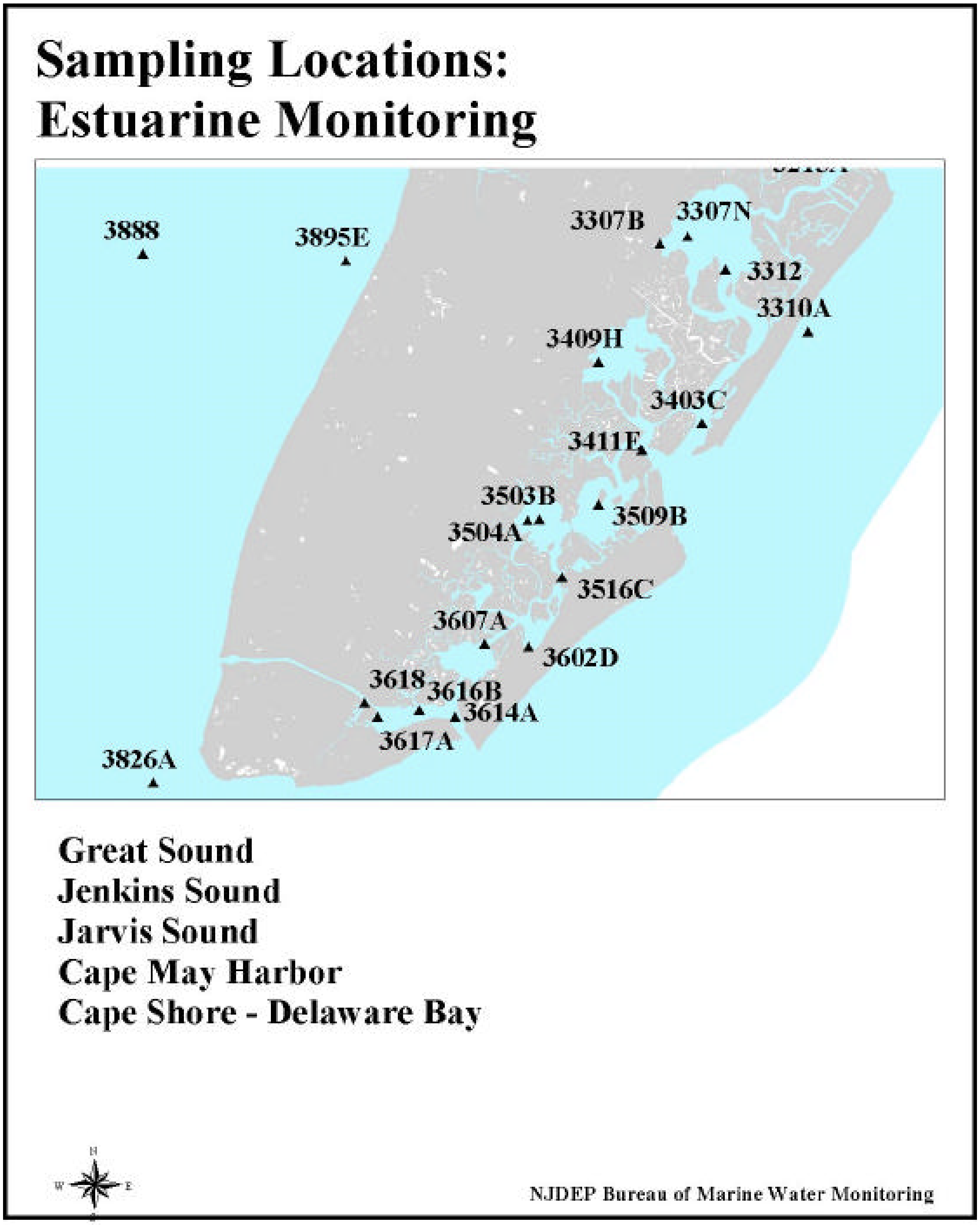

Figure 62: Sampling Stations in the vicinity of Cape May Inlet

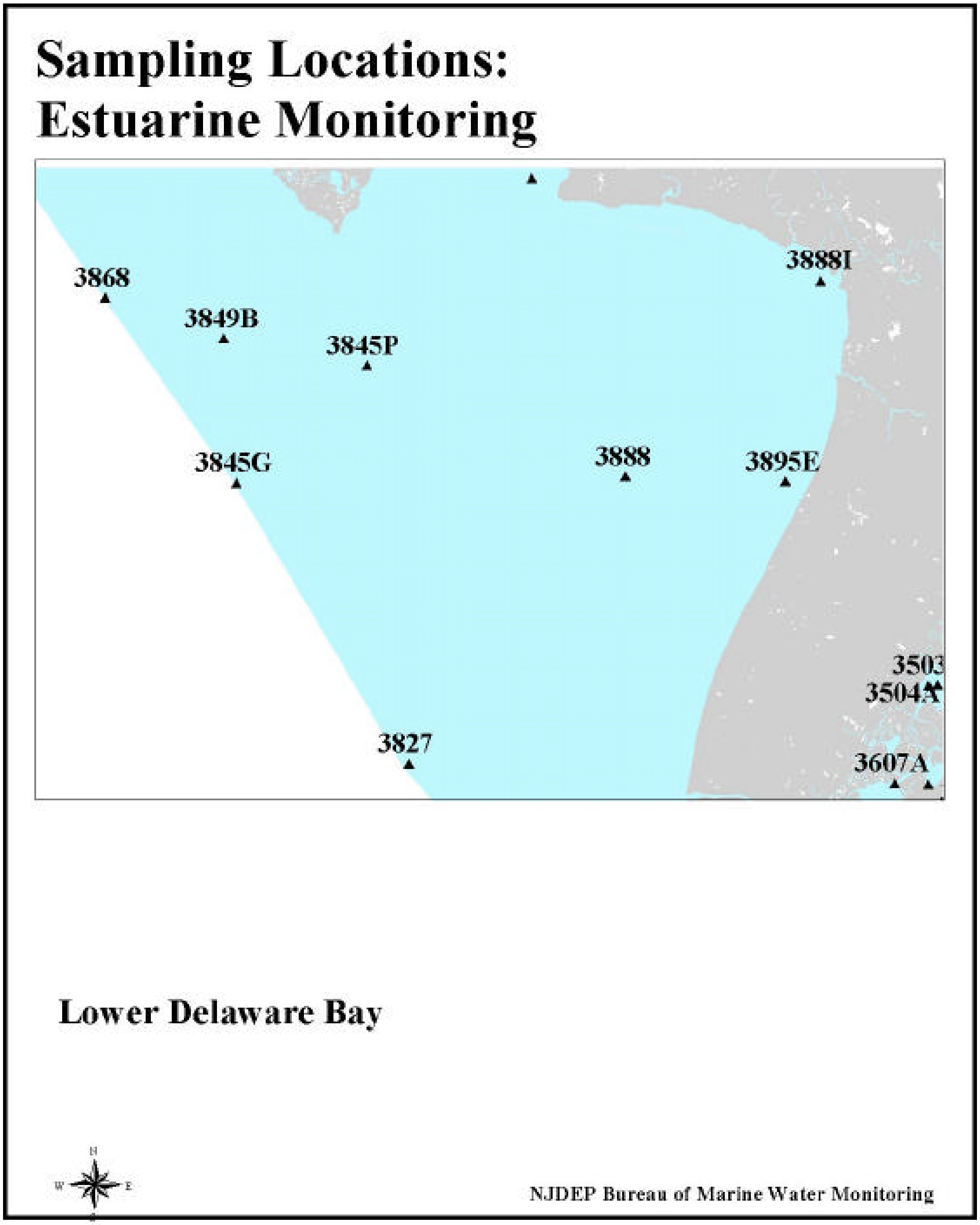

Figure 63: Sampling Stations in the vicinity of the Lower Delaware Bay

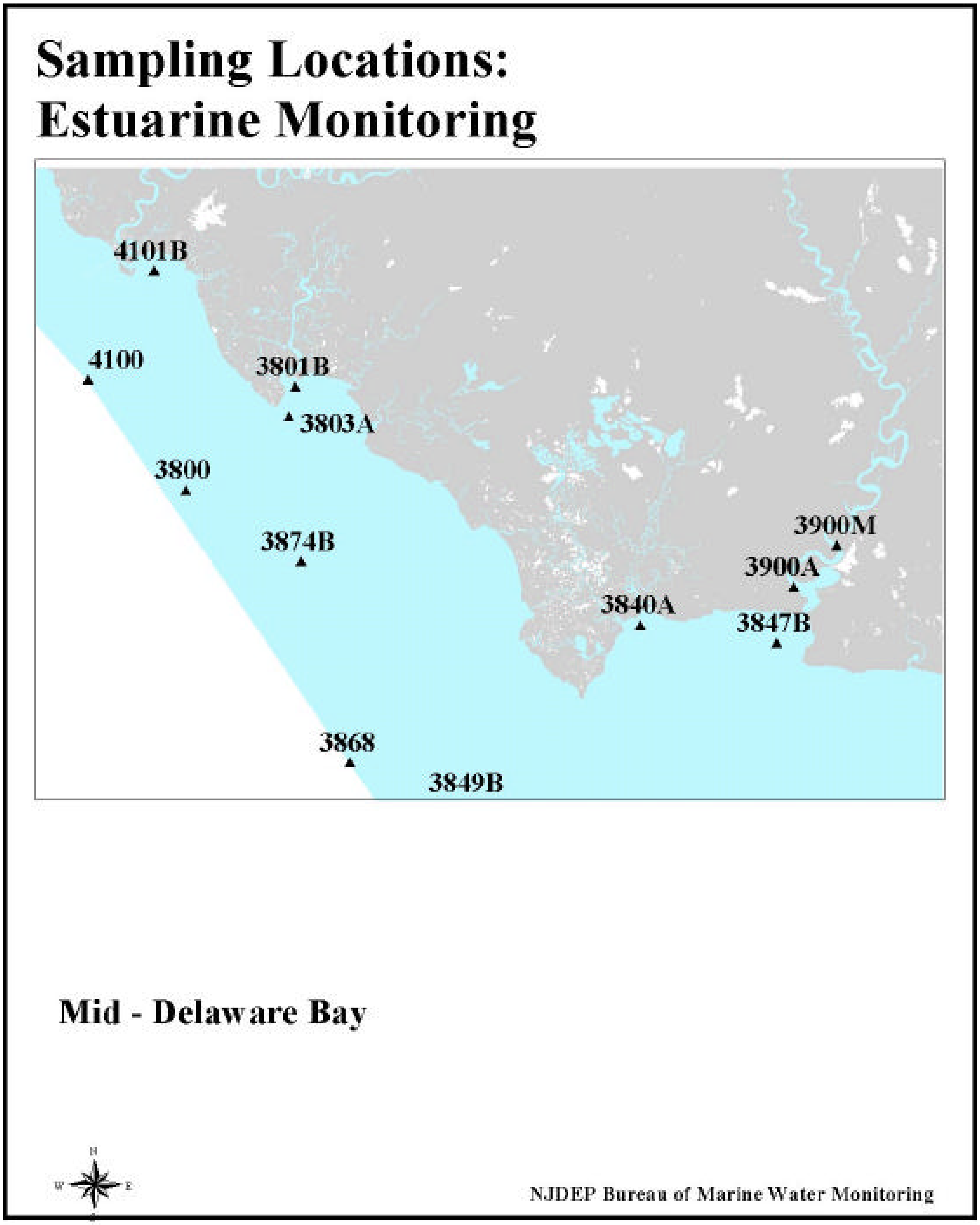

Figure 64: Sampling Stations in the vicinity of the Maurice River

APPENDIX III. DATA SUMMARIES BY LOCATION

The following tables show the average value of the indicated parameters. These are grouped according to estuary type and are further sub-grouped by location.

	ESTUARINE – RIVER DOMINATED			
	RARITAN BAY	**SANDY HOOK BAY**	**NAVESINK RIVER**	**SHREWSBURY RIVER**
TEMPC	16.2	16.8	16.9	14.9
SALINITY	25.2	25.6	20.8	23.1
SECCHI	4.4	4.5	3.9	4.0
TSS	37.2	42.0	40.2	45.6
DO % SAT	90.8	99.6	87.0	90.3
NH_3	151.4	89.2	88.1	96.5
NO_3	267.0	174.9	143.9	217.0
PO_4	67.2	61.0	92.9	87.5
TON	854.9	659.7	662.1	745.1
N:P	12.0	6.8	6.0	6.5
Fecal Coliform MPN (geometric mean)	4.8	3.9	17.8	7.5
	MANASQUAN RIVER	**MULLICA RIVER**	**PATCONG CREEK**	**GREAT EGG RIVER**
TEMPC	15.8	15.1	21.2	21.3
SALINITY	23.4	17.7	24.9	21.4
SECCHI	4.8	3.2	1.9	2.6
TSS	42.4	29.1	41.2	46.0
DO % SAT	73.6	67.2	73.9	71.5
NH_3	44.6	46.6	70.1	70.9
NO_3	68.0	29.7	22.9	26.3
PO_4	22.5	19.5	23.9	28.0
TON	474.8	354.7	379.5	375.3
N:P	7.9	4.6	4.3	4.1
Fecal Coliform MPN (geometric mean)	21.8	12.3	8.3	29.4

	ESTUARINE – RIVER DOMINATED			
	MIDDLE RIVER	TUCKAHOE RIVER	DENNIS CREEK	MAURICE RIVER COVE
TEMPC	18.5	18.9	20.7	17.9
SALINITY	20.4	23.2	18.2	17.9
SECCHI	2.1	1.9	1.3	1.2
TSS	49.6	41.4	38.8	44.9
DO % SAT	65.1	76.5	98.9	76.3
NH_3	67.1	114.6	161.7	191.1
NO_3	22.1		106.1	248.3
PO_4	19.7	28.3	46.9	58.3
TON	420.9	362.3	710.3	883.3
N:P	4.8	4.2	7.2	9.2
Fecal Coliform MPN (geometric mean)	20.1	12.9	3.0	42.2
	NANTUXENT COVE	COHANSEY COVE	DELAWARE BAY	RANGE OF VALUES
TEMPC	17.9	18.2	15.5	14.9 – 21.3
SALINITY	15.6	14.7	20.7	14.7 – 25.6
SECCHI	1.6	1.8	3.0	1.2 – 4.5
TSS	46.4	36.0	28.8	28.8 – 49.6
DO % SAT	89.8	89.1	96.0	65.1 – 99.6
NH_3	63.5	54.8	58.3	44.6 – 191.1
NO_3	392.5	354.0	301.4	22.1 – 392.5
PO_4	46.0	48.3	32.1	19.5 – 92.9
TON	878.8	687.4	641.4	354.7 – 883.3
N:P	10.6	10.4	13.0	4.1 – 13.0
Fecal Coliform MPN (geometric mean)	17.6	4.1	3.6	3.0 – 42.2

	ESTUARINE – SHALLOW			
	SHARK RIVER	GREAT BAY	BARNEGAT BAY	
TEMPC	14.4	14.0	16.4	
SALINITY	31.6	25.4	22.4	
SECCHI	4.9	3.4	3.1	
TSS	42.9	38.1	38.4	
DO % SAT	75.1	57.9	82.9	
NH_3	33.7	38.7	18.0	
NO_3	35.7	29.9	18.6	
PO_4	30.6	24.5	18.7	
TON	333.6	354.3	440.8	
N:P	2.2	3.5	3.2	
Fecal Coliform MPN (geometric mean)	41.1	5.6	7.8	
	BARNEGAT BAY			
	WESTECUNK CREEK	MANAHAWKIN BAY	MILL CREEK	LITTLE EGG HARBOR
TEMPC	15.1	17.2	17.1	15.9
SALINITY	25.9	28.7	26.0	29.9
SECCHI	2.9	2.9	2.9	4.0
TSS	26.4	53.4	39.6	36.7
DO % SAT	64.6	64.3	66.2	63.6
NH_3	22.7	16.2	28.9	27.0
NO_3	13.0	8.7	21.2	15.2
PO_4	20.9	17.6	20.3	21.1
TON	467.9	498.0	534.8	337.8
N:P	2.9	3.8	6.4	2.6
Fecal Coliform MPN (geometric mean)	26.0	5.1	13.7	4.7

	ESTUARINE – SHALLOW			
	ABSECON INLET AREA			
	LITTLE BAY	REED BAY	ABSECON CREEK	ABSECON BAY
TEMPC	16.6	16.7	17.2	16.1
SALINITY	30.2	30.1	24.8	30.8
SECCHI	3.7	3.1	3.1	3.4
TSS	51.4	49.7	92.0	61.1
DO % SAT	57.7	50.6	56.1	51.8
NH_3	51.2	98.8	121.5	75.6
NO_3	21.3	28.5	32.1	21.8
PO_4	26.2	35.9	31.4	32.9
TON	330.6	385.9	408.4	305.7
N:P	2.8	3.9	5.8	3.4
Fecal Coliform MPN (geometric mean)	6.5	4.5	37.2	6.1
	BEACH THOROFARE	INSIDE THOROFARE	LUDLAM BAY	
TEMPC	15.8	17.0	14.0	
SALINITY	31.0	29.4	32.2	
SECCHI	3.5	4.7	2.9	
TSS	36.5	47.2	45.0	
DO % SAT	59.3	57.4	88.1	
NH_3	64.7	55.0	46.8	
NO_3	33.7	37.3	12.3	
PO_4	38.4	45.6	39.0	
TON	315.1	401.5	319.4	
N:P	3.4	2.6	1.9	
Fecal Coliform MPN (geometric mean)	24.3	36.1	8.6	

	ESTUARINE – SHALLOW			
	GREAT EGG HARBOR INLET			
	LAKES BAY	SCULL BAY	GREAT EGG HARBOR	PECK BAY
TEMPC	17.5	16.9	19.4	17.8
SALINITY	30.9	30.4	29.1	26.7
SECCHI	3.6	3.8	3.0	1.6
TSS	46.8	57.6	52.2	35.2
DO % SAT	59.9	54.3	82.0	86.0
NH_3	64.3	74.1	52.6	72.2
NO_3	36.6	32.8	25.0	21.2
PO_4	47.5	37.0	29.5	32.0
TON	393.3	379.0	330.3	362.5
N:P	3.1	4.1	3.1	3.3
Fecal Coliform MPN (geometric mean)	14.5	7.4	6.7	13.9
	HEREFORD INLET AREA			
	GREAT SOUND	JENKINS SOUND	GRASSY SOUND	RICHARDSON SOUND
TEMPC	16.1	15.5	16.3	16.4
SALINITY	31.5	31.2	26.0	26.1
SECCHI	1.8	1.4	2.0	1.9
TSS	55.5	42.2	30.4	44.0
DO % SAT	82.3	87.3	92.4	87.5
NH_3	98.9	52.2	33.5	40.5
NO_3	12.5	10.0	9.2	10.8
PO_4	47.7	20.0	18.1	19.7
TON	449.2	30.3	242.4	313.0
N:P	2.9	3.3	2.5	2.5
Fecal Coliform MPN (geometric mean)	6.9	8.1	6.5	5.5

	ESTUARINE – SHALLOW			
	CAPE MAY AREA			
	SUNSET LAKE	JARVIS SOUND	CAPE MAY CANAL	CAPE MAY HARBOR
TEMPC	18.8	18.8	18.2	17.8
SALINITY	31.9	32.0	31.6	31.8
SECCHI	2.2	3.8	2.8	2.8
TSS	46.0	48.0	60.8	38.0
DO % SAT	86.3	84.2	82.0	83.5
NH_3	69.2	56.7	88.5	120.0
NO_3	11.5	14.0	16.2	14.3
PO_4	35.4	31.9	32.6	29.0
TON	398.4	359.8	442.0	344.3
N:P	2.4	2.5	3.7	4.4
Fecal Coliform MPN (geometric mean)	14.9	114.8	26.6	3.0
	RANGE OF VALUES			
	BARNEGAT BAY	ABSECON INLET	GREAT EGG / HEREFORD	CAPE MAY
TEMPC	15.1 – 17.2	14.0 – 17.2	15.5 – 19.4	17.8 – 18.8
SALINITY	22.4 – 29.9	24.8 – 32.2	26.0 – 31.5	31.6 – 32.0
SECCHI	2.9 – 4.0	2.9 – 4.7	1.4 – 3.8	2.2 – 3.8
TSS	26.4 – 53.4	36.5 – 92.0	30.4 – 57.6	38.0 – 60.8
DO % SAT	63.6 – 82.9	50.6 – 88.1	54.3 – 92.4	82.0 – 86.3
NH_3	18.0 – 28.9	28.9 – 121.5	33.5 – 98.9	56.7 – 120.0
NO_3	8.7 – 21.2	12.3 – 37.3	9.2 – 36.6	11.5 – 16.2
PO_4	17.6 – 21.1	20.3 – 45.6	18.1 – 47.5	29.0 – 35.4
TON	337.8 – 534.8	305.7 – 408.4	30.3 – 449.2	344.3 – 442.0
N:P	2.6 – 6.4	1.9 – 5.8	2.5 – 4.1	2.4 – 4.4
Fecal Coliform MPN (geometric mean)	4.7 – 26.0	4.5 – 37.2	5.5 – 14.5	3.0 – 114.8

	INLETS			
	ATLANTIC OCEAN	SHARK RIVER	MANASQUAN	BARNEGAT
TEMPC	22.7	23.2	16.2	16.0
SALINITY	31.9	30.7	27.7	30.6
SECCHI			6.3	3.6
TSS	34.7	35.3	40.8	46.7
DO % SAT	108.5	128.1	84.5	68.8
NH_3			51.9	15.0
NO_3	63.9	59.0	70.6	25.1
PO_4	20.7	11.0	21.4	20.5
TON	219.1	219.1	363.4	306.8
N:P			7.9	1.6
Fecal Coliform MPN (geometric mean)			27.6	4.9
	LITTLE EGG	ABSECON	GREAT EGG	CORSONS
TEMPC	13.8	22.8	16.5	15.2
SALINITY	31.3	32.6	31.6	32.2
SECCHI	4.4		4.1	3.2
TSS	34.7	41.3	55.2	40.6
DO % SAT	68.8	111.9	67.5	95.4
NH_3	58.5		41.9	28.8
NO_3	38.1	63.9	33.7	13.9
PO_4	24.8	20.7	26.8	26.4
TON	267.3	243.2	289.3	256.7
N:P	3.8		3.1	2.2
Fecal Coliform MPN (geometric mean)	4.3		6.8	5.0

	INLETS			
	TOWNSEND	HEREFORD	CAPE MAY	RANGE ALL INLETS
TEMPC	13.7	13.8	17.8	13.7 – 23.2
SALINITY	32.1	31.8	32.0	27.7 – 32.6
SECCHI	3.3	3.1	3.8	3.1 – 6.3
TSS	38.6	43.9	37.3	34.7 – 55.2
DO % SAT	87.5	93.9	91.3	67.5 – 128.1
NH_3	36.5	33.1	53.9	15 – 58.5
NO_3	15.4	17.1	17.2	13.9 – 70.6
PO_4	27.9	17.8	21.3	11.0 – 27.9
TON	273.0	252.2	287.8	219.1 – 363.4
N:P	1.9	2.5	2.5	1.6 – 7.9
Fecal Coliform MPN (geometric mean)	6.1	7.3	12.2	4.3 – 27.6

	OCEAN	OCEAN NEAR OUTFALL
TEMPC	22.2	22.7
SALINITY	31.8	31.1
SECCHI		
TSS	38.8	41.7
DO % SAT	115.2	126.5
NH_3		
NO_3	63.9	61.8
PO_4	11.0	10.7
TON	243.2	278.6
N:P		
Fecal Coliform MPN (geometric mean)		

	RIVERS			
	SWIMMING RIVER	MANASQUAN RIVER	TOMS RIVER	MULLICA RIVER
TEMPC	10.0	16.2	17.3	14.9
SALINITY	0.2	13.6	11.6	10.7
SECCHI	2.0	2.9	2.9	3.0
TSS	26.4	36.8	15.6	17.2
DO % SAT	90.1	80.8	82.8	75.2
NH_3	26.4	45.9	41.7	46.7
NO_3	946.9	122.6	96.4	27.8
PO_4	11.6	34.5	16.8	15.9
TON	1097.2	590.7	517.9	347.0
N:P	83.9	9.6	12.5	5.2
Fecal Coliform MPN (geometric mean)	4.7	163.4	20.3	35.7

	GREAT EGG RIVER	MAURICE RIVER	RANGE ALL RIVERS
TEMPC	21.6	18.8	10.0 – 21.6
SALINITY	6.1	14.3	0.2 – 14.3
SECCHI	2.1	1.1	1.1 – 3.0
TSS	27.1	43.6	15.6 – 43.6
DO % SAT	68.6	75.8	68.6 – 82.6
NH_3	38.7	204.5	26.4 – 204.5
NO_3	72.3	257.1	27.8 – 946.9
PO_4	15.5	58.7	11.6 – 58.7
TON	452.0	735.6	347 - 1097
N:P	13.7	9.1	5.2 – 83.9
Fecal Coliform MPN (geometric mean)	103.9	147.2	4.7 – 163.4

	TIDAL TRIBUTARY			
	METEDECONK RIVER	KETTLE CREEK	SILVER BAY	CEDAR CREEK
TEMPC	9.0	10.0	10.0	9.0
SAL	0.2	0.1	2.4	0.1
SECCHI	1.0	1.0	2.0	2.0
TSS				
DO % SAT	60.8	83.5	91.0	76.7
NH_3	52.1	29.0	46.4	20.1
NO_3	679.4	852.0	971.8	37.3
PO_4	7.5	6.2	3.3	2.5
TON	971.5	1030.2	1799.1	170.5
N:P	98.4	141.4	573.7	23.1
Fecal Coliform MPN (geometric mean)	31.4	5.2	19.9	3.0
	FORKED RIVER	OYSTER CREEK	WARETOWN CREEK	RANGE ALL TIDAL TRIBUTARIES
TEMPC	10.0	10.0	10.0	9 - 10.0
SAL	0.1	0.1	0.1	0.1 – 2.4
SECCHI	2.5	1.5	1.0	1 – 2.5
TSS				
DO % SAT	74.2	80.4	83.9	60.8 – 91.0
NH_3	20.4	12.0	20.1	12.0 – 52.1
NO_3	33.3	10.5	42.7	10.5 – 971.8
PO_4	3.1	2.0	4.5	2.0 – 7.5
TON	230.7	194.3		170 – 1799.1
N:P	17.3	11.3	14.0	3.0 – 573.7
Fecal Coliform MPN (geometric mean)	15.0	3.6	43.0	3.0 – 43.0

APPENDIX IV. RAW DATA LISTING

Station number in ascending order lists: Field measurements, laboratory measurements and calculated values on the following pages.

Data coding is according to EPA protocols whereby "K" means that the concentration was less than the listed value, "L" means that it was greater than the listed value and "J" means the value was estimated.

Tide stage is listed according to a standard EPA five digit code. The 3rd - 5th digits represent the time after the change of tide. The 3rd digit is hours. The 4th and 5th digits are the minutes. The 1st digit is either 1 or 0. 1 means the tide was high at the last change of tide and 0 means that the tide was low at the last change of tide. The 2nd digit is always 1. Therefore, a code of 11245 would mean that the tide was 2 hours and 45 minutes into ebb at the station at the time of sample collection.